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Size selection of whitefish (*Coregonus maraena*) in a pontoon trap equipped with an encircling square mesh selection panel

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ABSTRACT

Many fishing methods result in significant catches of non-target species or individuals that are too small to be retained for economic values or within quota regulations. In the Baltic Sea trap fishery, the major problem is the bycatch of juvenile and non-marketable whitefish (*Coregonus maraena*) which constitutes a threat to the sustainability of the fishery and a time-consuming problem for the fishers. This study evaluates the effectiveness of a modified fish trap in reducing such bycatch. An encircling selection panel consisting of 50 × 50 mm square mesh netting was installed in a pontoon fish chamber of a salmon/whitefish trap. Comparative fishing was conducted against a control trap without selection panel in the inshore waters of the Bothnian Sea. Comparisons of catch compositions between the traps showed that there was a 72% reduction in juvenile whitefish catch in the experimental trap. The length at 50% retention (30.1 cm) corresponded well to the minimum market size (>30 cm) of whitefish that are desired for the local market. Fishers are advised to use a netting panel of 50 × 50 mm square mesh for their traps to reduce undersized whitefish. The results are important for the sustainability of whitefish stocks in the Baltic Sea.

1. Introduction

The commercial catches of whitefish (*Coregonus maraena*) in the Swedish part of the Baltic and Bothnian Seas have decreased significantly. During the late 1980s, the annual commercial landing reached 1000 t in the Bothnian Bay alone (Byström and Hudd, 2010). Since 2000, catches have decreased from 276 to 139 t (Swedish Agency for Marine and Water Management, 2013). Currently, landing by the recreational fishery are believed to be larger than that by the commercial fishery (Swedish Board of Fisheries, 2011).

One possible cause of the decreased landing of whitefish is overfishing. Overfishing has globally led to severe depletion or even extinction of many fish stocks and is one of the most influencing disturbances on coastal ecosystems (Jackson et al., 2001). Contributing causes for the decline of whitefish may be the increased populations of grey seals (*Halichoerus grypus*) (Karlsson and Helander, 2005) and cormorants (*Phalacrocorax carbo*) (Bregnballe et al., 2003), large scale environmental changes (Walther et al., 2002), loss of reproduction areas, or a combination of these factors.

There are two types of whitefish in the Baltic and Bothnian Sea: localized and migrating (Svärdson, 1979). Migrating whitefish are artificially fertilized, hatched and reared in hydropower compensation schemes and released as young in Finnish and Swedish rivers. These two types of fish are difficult to distinguish visually and are not separated in the commercial catch statistics. Therefore, it is difficult to estimate the population status for each type. On the Swedish side of the Bothnian Sea, management actions such as closed fishing seasons and establishment of protected areas have been taken. In 2011, the whitefish of the Gulf of Bothnia became red-listed by the World Wildlife Fund.

In the commercial fishery of the Baltic and Bothnian Seas, whitefish are often caught using traps in inshore waters (Lehtonen and Suuronen, 2004). The type of trap that dominates the fishery is the push-up trap, also called the pontoon trap (Fig. 3) (Lunneryd et al., 2003; Suuronen et al., 2006; Hemmingsson et al., 2008; Lundin

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et al., 2011a; Suuronen et al., 2012). The push-up trap was primarily developed for the salmon (*Salmo salar*) and trout (*Salmo trutta trutta*) fishery. More recently it has been modified to also catch whitefish. The development of the push-up trap was a response to the increased population of grey seals that caused damage to the traditional traps and the catches therein. The push-up trap has been shown to be effective despite presence of intrusive grey seals (Lunneryd et al., 2003; Varjopuro, 2011).

One challenge with push-up traps and other types of traps is that they often catch small (young) fish as bycatch (Tschernij et al., 1993; Lundin et al., 2011a,b). This fish is usually thrown overboard and suffers high mortality in the process (Davis, 2002). This is a waste of a valuable natural resource and may also deplete the fish stock. Additionally, the time spent on sorting and grading fish may lower profitability in the fishery (Hall et al., 2000). Since bycatch and discards are threats to fish stocks and ecosystems worldwide (Alverson et al., 1994), reduction of bycatch should therefore be prioritized in gear development.

Studies have shown that undersized fish can be excluded from the catch in push-up traps with a selection panel (Lundin et al., 2011a). A successful design for excluding juvenile herring (*Clupea harengus membras*) was large grids with vertical steel bars that encircled the fish chamber of the push-up trap (Lundin et al., 2011b). The passage through such grids did not affect the short term mortality of herring (Lundin et al., 2012), indicating that escapees have a good chance of survival.

Only a couple of studies have been conducted on size selection of whitefish in the whitefish fishery. Lundin (unpublished data) found that a selection panel of square mesh Dyneema® netting was more effective than vertical steel bars in excluding small whitefish from the catch. In the same study, a square mesh size of 50 × 50 mm was found to be the best for excluding whitefish under 30 cm, which are too small for the market. The area of the selection panel used in Lundin (unpublished data) was only 400 × 350 mm, and it was concluded that a larger panel would improve the overall efficiency of the size selection. Small selection panels, such as the one used in Lundin (unpublished data) are often installed in traps by the fishers themselves.

The location where the panel should be placed for optimized selection is still in question. An optimized placement of a selection panel depends mainly on the behaviour of the fish and on external factors such as water currents (Lundin et al., 2011a). Better knowledge on the design and placement of selection panels/grids would be a step towards a sustainable fishery. This was the general objective of the present study.

The specific objectives of the present study were threefold. First, to calculate the efficiency in reducing bycatch of small whitefish when using a large encircling selection panel in a salmon/whitefish trap. Second, to produce the L25 (the length of whitefish at a 25% probability to be retained), L50, L75 and the SR (the difference between L25 and L75) of the selection panel by fitting a logistic selection curve to the data. Third, to determine the appropriate location of a selection panel by analyzing where the most of the whitefish escaped.

2. Material and methods

2.1. Study period and area

Field experiments were conducted between the 21st of June and the 20th of August 2012. The study area was the Swedish inshore waters of the Bothnian Sea, near the mouth of the River Indal (62°23′N, 17°31′E; Fig. 1). The area has been subject to intensive fishing for centuries. However, since the 1990s, the number of fishers in the area has decreased significantly, the main reason being the increased grey seal population that damages the gear and catch, resulting in loss of profit for the fishing industry. The large number of grey seals in combination with a large number of migrating salmon has made the area a popular place for testing methods that reduce the seal damage on fishing gears (Lunneryd et al., 2003). Today, a few fishers are still active in the area, and most of them have been able to continue due to investments in seal-safe pontoon traps.

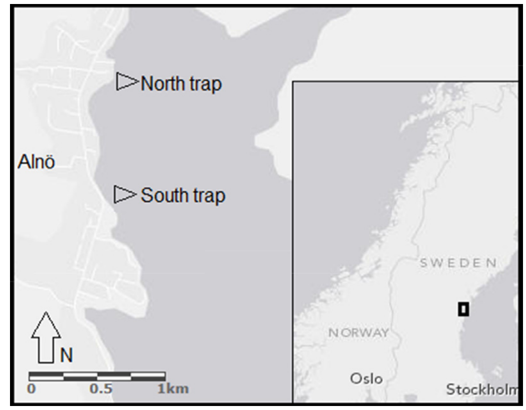

Fig. 1. The location of the experiment.

2.2. Gear

Two pontoon traps equipped with detachable pontoon fish chambers were used simultaneously during the experiment (Fig. 2). Both traps were placed at a depth of 9 m and were separated by a distance of 800 m. One of the traps was located closer to the river mouth and is referred to as the northern trap. The traps were of the same design except for the differences being tested.

2.3. Selection panel

One of the two pontoon fish chambers was equipped with a selection panel. The selection panel replaced a section of inner netting between the first two aluminium rings in the fish chamber structure. It encircled the pontoon fish chamber (Fig. 3). The total length of the selection panel was 1.25 m, with a circumference of 7.5 m. This represented 26% of the total inner netting area. The

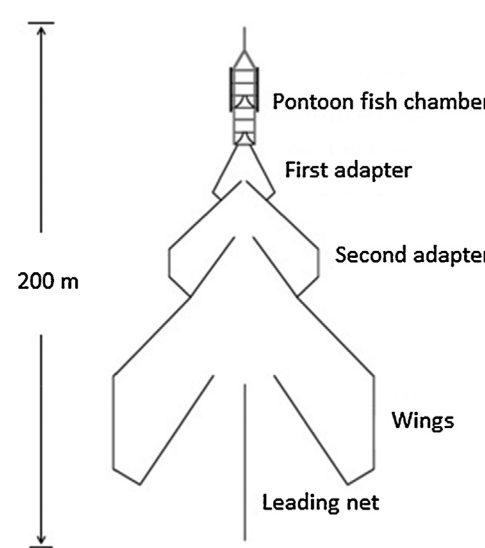

Fig. 2. Outline of the complete whitefish/salmon trap.

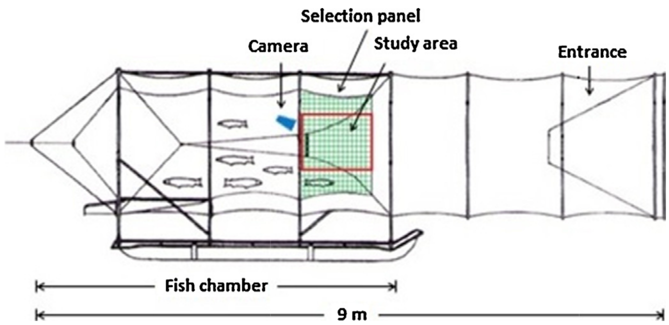

Fig. 3. The northern side of the experimental pontoon fish chamber with 50 mm square mesh selection panel, showing the placement of one camera and corresponding study area. The set-up was identical on the southern side.

material of the selection panel was square mesh Dyneema® netting, 2 mm twine diameter, with 50 mm bar length. The selection panel was video-recorded from both sides of the fish chamber with two underwater cameras (WAT-902H monochrome camera manufactured by Watec). The cameras were focused on study areas which covered 1.25 × 1 m of the central part of the panel. The video footage was saved on a CamDisc Recorder and the software for viewing the recorded material was CamControl player v.3.29.

2.4. Data collection and analysis

The fish chamber with and without the selection panel were exchanged between traps every two weeks, resulting in a total of four replicates during the experiment. Traps were hauled 28 times in 60 days, mostly on the every other day. The total length of all whitefish in both traps was measured on 25 hauls. The lengths were rounded down to the nearest 5 mm length class. Salmon and trout were counted and weighed individually. The selection efficiency (the number of escapees divided by the number of potential escapees caught) of the experimental trap was tested by comparing the proportion of undersized whitefish caught in each trap. Since the data on whitefish lengths passed the test for homogeneity of variance, the difference in mean length of whitefish was tested with unpaired *t*-test.

The SELECT method for paired-gear experiments (Millar and Walsh, 1992; Millar and Fryer, 1999) was used for obtaining the selection parameters by fitting a symmetric logistic selection curve to the data. The SELECT method is essentially developed to analyze trawl data (e.g. Sistiaga et al., 2009) but it also functions to analyze data from passive gears such as pots (Ovegård et al., 2011) and traps (Stewart and Ferrell, 2003). The method uses maximum likelihood for the fitting and it includes a measurement of the relative fishing efficiency of the experimental and control gears (p). A selection curve was fitted for both the assumption of equal fishing power ($p = 0.5$) and for p estimated (p-est). The lengths at 25, 50, 75% retention and the selection range (SR) were estimated. The best fit was found by a likelihood ratio test. The software used was Russell B Millar's R-code for fitting SELECT models to covered codend and alternate hauls data (Millar, 2004). For a more detailed description of the SELECT functions see Millar and Walsh (1992).

The camera recordings started on 12th July and ended on 12th August. A total of 349 h of recordings were collected from each camera, evenly distributed over the time period. The recordings were viewed, and all escaping whitefish and salmonid smolts were registered. For each escapee, the date, time and the position of where the fish passed through the study area were noted. The position of where the fish passed through the selection panel was analyzed and visualized in Mathematica (Wolfram Research, Inc., Version 9.0, Champaign, IL (2010)) by adapting a Smooth Kernel Distribution to the data (Duong and Hazelton, 2003). See Fig. 3 for illustration of the study area. The positions from both study areas were mirrored and combined into a single visualization. Aggregations were highlighted by dividing the study area into 20 squares of cell size 5 × 5 meshes. A chi-square test was used to test if the distribution for the chosen cell size was different from randomness.

Table 1
Total number of individuals caught in the pontoon traps.

	Whitefish (n)	Salmon (n)	Salmon Smolt (n)	Trout (n)
Experimental trap	488	102	0	19
Control trap	1003	75	30	37

3. Results

3.1. General

The total number of whitefish caught and measured in the experiment was 1491 (Table 1). The number of salmon caught was 177 and the number of trout caught was 58. Significantly more whitefish were caught in the control trap ($n = 1003$) compared to in the experimental trap ($n = 488$; Mann–Whitney U-test, $p < 0.01$, Table 2).The catch per haul was significantly larger on the northern site ($n = 1322$) compared to the southern site ($n = 169$; Mann–Whitney U-test, $p < 0.01$, Table 2).

3.2. Selection efficiency

Undersized whitefish (<30 cm) caught in the experimental and control traps represented 9% and 32%, respectively (Fig. 4). The 23% reduction of undersized whitefish results in a selection efficiency of 72%.

Whitefish caught in the experimental trap had a significantly larger mean length (34.8 ± 3.8 cm; 22.0–47.0 cm) than those caught in the control trap (31.8 ± 4.9 cm; 21.0–52.5 cm; t-test, $p < 0.01$).

3.3. SELECT-model

The relative fishing efficiency for whitefish in the experimental trap was significantly lower than 0.5 ($p < 0.01$). An estimated parameter p gave the best model fit for the data. The calculated length at 50% retention was 30.1 cm and the selection range was 3.0 cm (Table 3, Figs. 5 and 6).

3.4. Video analysis

In all, 59 whitefish were observed escaping the study areas. The largest number (34) escaped to the north facing currents from the river, and 25 to the south. In addition, three salmonid smolts were observed escaping northwards.

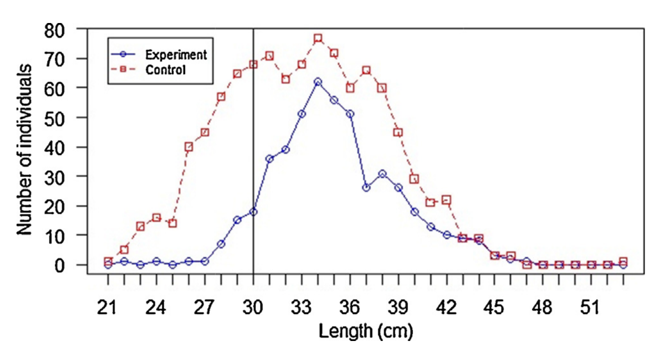

Fig. 4. Length frequencies of all whitefish caught in the experimental and control trap. The vertical line indicates the minimum market size.

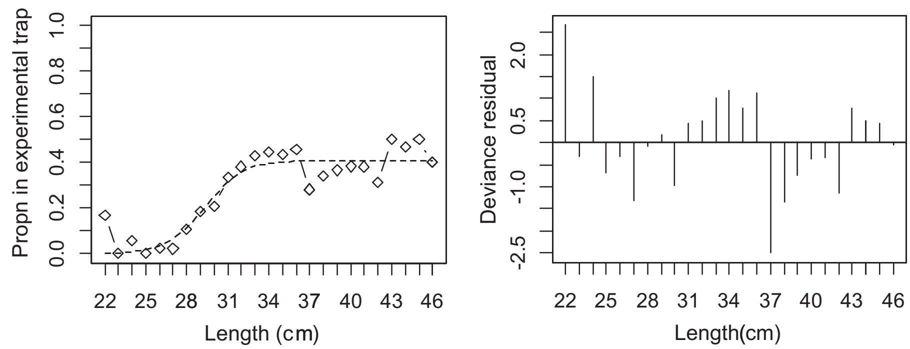

Fig. 5. Plot of the proportion of whitefish caught in the experimental trap. The dashed symmetric line represents the fitted logistic retention probability function with parameter p estimated. The right plot shows the residuals of the fitted function.

Table 2
Number of individuals caught in the experimental and control trap per haul (E: experimental trap, C: control trap, N: Northern trap site, S: Southern trap site).

Replicate	Haul	Date	Trap	Position	Whitefish (*n*)
1	1	06–26	E	S	13
			C	N	34
	2	06–28	E	S	5
			C	N	26
	3	07–04	E	S	1
			C	N	41
2	4	07–06	E	N	4
			C	S	2
	5	07–08	E	N	20
			C	S	3
	6	07–12	E	N	18
			C	S	8
	7	07–15	E	N	61
			C	S	6
	8	07–16	E	N	41
			C	S	6
	9	07–17	E	N	49
			C	S	3
	10	07–18	E	N	28
			C	S	3
3	11	07–20	E	S	3
			C	N	70
	12	07–22	E	S	5
			C	N	111
	13	07–24	E	S	12
			C	N	160
	14	07–25	E	S	2
			C	N	61
	15	07–26	E	S	0
			C	N	16
	16	07–27	E	S	0
			C	N	86
	17	07–29	E	S	2
			C	N	159
	18	07–30	E	S	2
			C	N	39
	19	07–31	E	S	0
			C	N	56
	20	08–01	E	S	0
			C	N	20
4	21	08–03	E	N	22
			C	S	7
	22	08–08	E	N	27
			C	S	56
	23	08–10	E	N	108
			C	S	10
	24	08–13	E	N	58
			C	S	9
	25	08–15	E	N	7
			C	S	11

Table 3
Parameter estimates (P: fishing efficiency, L25: length at 25% retention probability, L50: length at 50% retention probability, L75: length at 75% retention probability, SR: selection range) and model deviance (MD) for the two fitted SELECT models ($p=0.5$, $p=$estimated) and the deviance values for the hypotheses of equal fishing power (df: degrees of freedom, SE: standard errors).

Parameter	$p=0.5$	SE	$p=$est	SE
P	0.5		0.4	0
L25	29.5	0.3	28.6	0.4
L50	31.8	0.4	30.1	0.5
L75	34.2	0.6	31.6	0.7
SR	4.7	0.6	3.0	0.6
MD	50.2		28.8	
$H_0: p=0.5$				
Deviance			21.4	
df			1	
p-Value			<0.01	

Whitefish passing through meshes inside the study areas were not evenly distributed (Fig. 7). The distribution of the positions of escapes differed from randomness ($X^2=43.4$, $p<0.05$, d.f. = 19). The fish chose to pass through the study areas of the panel in the upper and front part most often.

Sixteen whitefish were seen squeezing through the mesh openings of the study area, 10 of them leaned over sideways so that their dorsal–ventral axis was in line with the diagonal axis of the square mesh before squeezing through. Eighteen whitefish were seen escaping in the background of the study area. The exact positions of their passage could not be confirmed but nine fish were seen near the top and 9 near the bottom of the fish chamber.

As a rule, whitefish passed through the meshes very cautiously. Even though 27% gently squeezed through the mesh within the study area, lost scales were only seen on one occasion. This was when a whitefish escaped in panic during lifting of the fish chamber

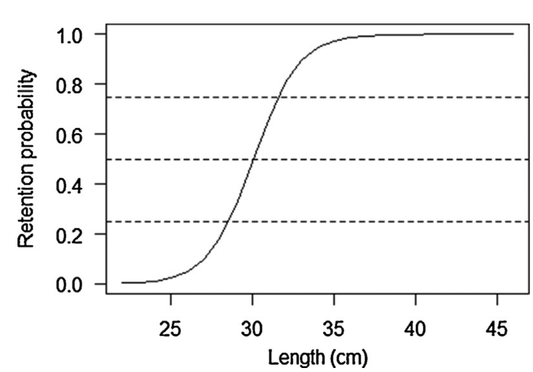

Fig. 6. Plot of the fitted logistic selection curve. Dashed lines represent the L25, L50 and L75.

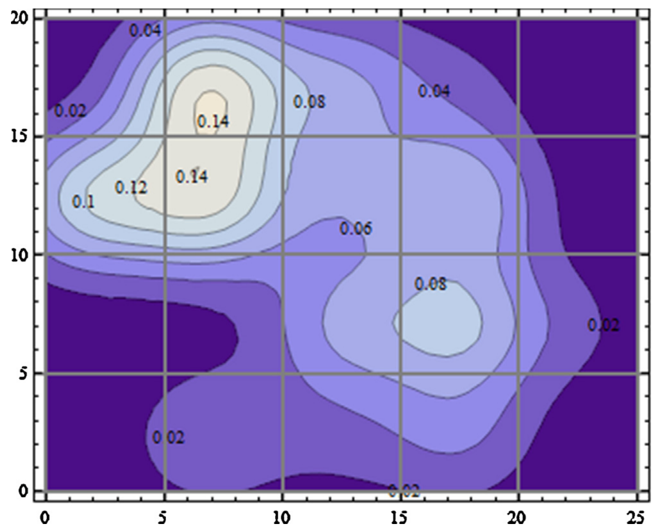

Fig. 7. Contour plot of the Smooth Kernel Distribution of the chosen cell size (5 × 5 meshes), representing the northern study area orientated as in Fig. 3, including the probabilities of escaping through certain cells of the combined study areas.

to the surface. No obvious stress behaviour or burst swimming was observed at any time.

4. Discussion

The selection efficiency of the 50 mm square mesh selection panel that encircled the fish chamber of the trap was 72% during the experiment, meaning that this proportion of the small (<30 cm) whitefish, otherwise captured, escaped through the panel. This result is similar to the efficiency of an encircling selection grid in a herring trap (Lundin et al., 2011b).

The length at 50% probability of retention (L50) was 30.1 cm, which corresponds to the lower size target of 30 cm of whitefish that is desired for the local market. The selection range (SR) of 3.0 cm indicates that the selection is sharper than what is normally achieved by selection devices in trawls (Sistiaga et al., 2009) and similar to what have been achieved by selection devices of other passive gears (Ovegård et al., 2011).

In the fishery, catch size and size of individual whitefish change during the season. The larger migratory whitefish is known to contribute a larger proportion of the total catch towards the end of the season. The proportion of the two whitefish forms in the catch might be different on different locations. In the present study, the experimental fish chamber and the control fish chamber were switched between trap positions every two weeks to minimize confounding effects. The distance between the two traps was set to be as close as possible in order to minimize potential differences in various factors, such as current, wind, temperature and different subspecies of whitefish being caught. The results derived should therefore be dependable. There was a larger catch of whitefish of all size classes in the control trap over the season. This was because the control trap was fishing at the most effective fishing site during the period with the largest catches (replicate 3, see Table 2).

Most of the whitefish observed escaping through the meshes inside the study areas escaped through the front and upper part of the panel. One explanation might be that the netting of the final entrance and the rear part of the panel merges in a wedge that becomes narrow for whitefish to swim in, and another explanation is that whitefish prefer swimming near the surface (Å. Andersson, pers. comm.). A higher proportion of whitefish escaped on the northern side of the fish chamber facing the water current from the river. A significantly higher rate of escapements towards the water current was also seen among herring in Lundin et al. (2011a). Of the whitefish seen escaping from other parts outside of the study areas, an equal number fled above and below the study area. This indicates that the efficiency of the encircling selection device is similar on the top and bottom areas. With respect to these results, we recommend that fishermen who attach smaller devices to their already existing traps should place them slightly higher than the vertical centre, ahead of the entrance and on the side of the fish chamber most commonly facing the water current.

Lundin et al. (2012) found that a grid passage in a pontoon trap did not affect the short-term mortality of herring. Herring is otherwise known to be vulnerable to physical contact. While the survival of escaped whitefish was not investigated in this study, our observations suggest that mortality of escapees is probably low. Only one fish was entangled and died, thus accidental losses were very minor.

No smolts were caught in the experimental trap, while 30 were caught in the control trap. A similar number of smolts probably swam into the experimental trap, but were able to escape through the selection device. The device is also thus likely to be important for the survival of young salmon in a coastal fishery with traps, improving the sustainability of salmonid stocks.

The selection device represented 26% of the total inner netting area of the fish chamber. To further increase the efficiency of releasing small whitefish, it might be a good idea to replace the entire inner netting with 50 mm square mesh. This would also reduce the cost and production time of the trap.

In conclusion, the selection panel reduced the amount of bycatch of young whitefish by 23% and the selection efficiency was 72%. The L50 was 30.1 cm which corresponds to the size of whitefish wanted for the local market. The whitefish preferred to escape through meshes slightly above the vertical centre of the fish chamber, about 1 m ahead of the wedge near the entrance and towards the current.

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