

Inverse modelling & classification of magnetic responses to improve marine UXO target selection

Oi 2024 - Data Interpretation & AI

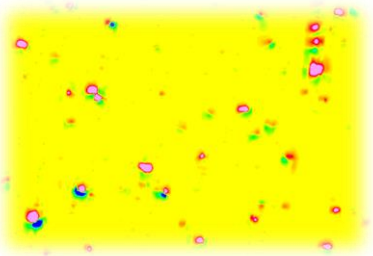
Jack Brighthouse



The problem

15%

UXO survey



Target list

Avoid / Investigate	Threat items			Non-UXO	
	GP 1000lbs bomb	SC-50 bomb	MK 17 mine	Miscellaneous	Geology
Y	20%	No match	82%	No match	No match
N	15%	No match	No match	No match	80%
N	No match	26%	No match	No match	No match
N	No match	12%	No match	61%	No match
Y	92%	No match	No match	No match	No match



Target rationalisation



Target identification
and clearance



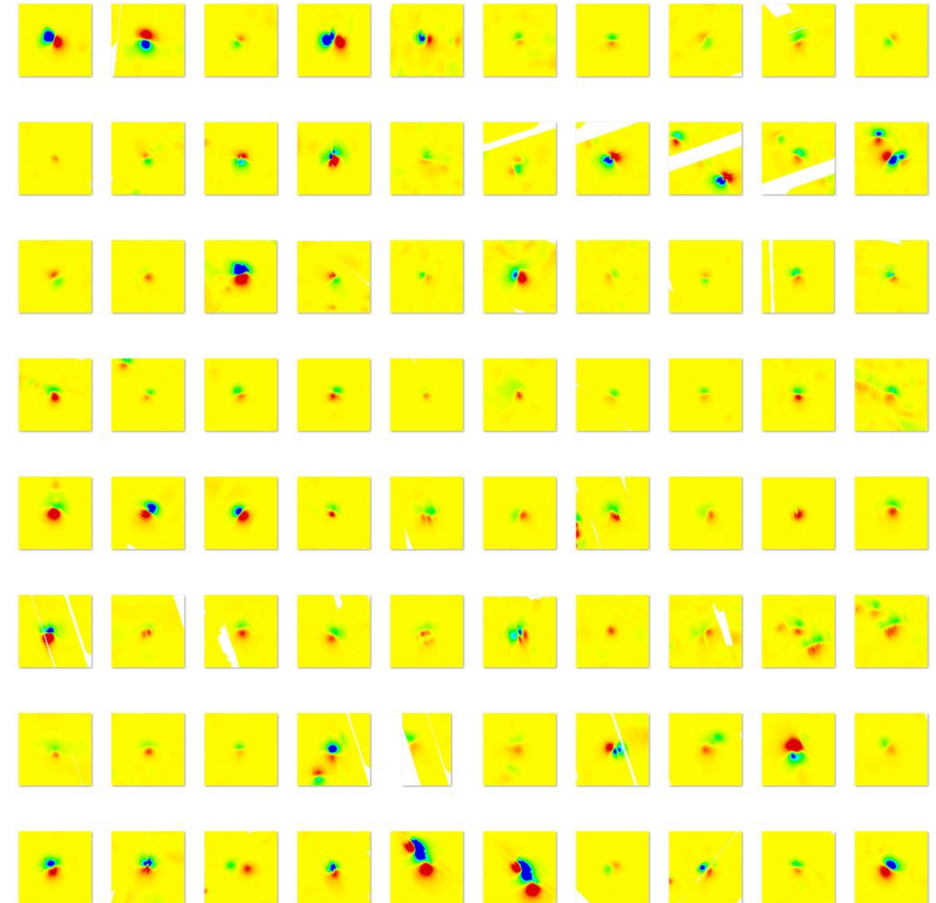
85%

<4% targets
investigated are
actually UXO

Objective

Use past projects data to better predict the magnetic response of potential UXO on future projects

- Implementable on live projects
- Tested and validated
- Documented and transparent



Use past projects data to better predict the magnetic response of potential UXO on future projects

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Inverse modelling and classification of magnetic responses to improve marine unexploded ordnance rationalization

Jack Brighouse¹,² Martin Wood,¹ Eoin McGregor,² Andrew Kirkland,³ David Sinclair,⁴ Dorte Reng Erbs-Hansen⁵ and Simon Hviid⁵

¹ALM Geophysics, The Old Counting House, Wallingford OX100BS, United Kingdom. E-mail: jack@almgeophysics.co.uk

²Vattenfall Vindkraft A/S, Jupitervej 6, 6000 Kolding, Denmark

³ScottishPower Renewables, 320 St Vincent St, Glasgow G25AD, United Kingdom

⁴TenneT, Eisenbahnlaßweg 2a, 31275 Lehrte, Germany

⁵Ørsted A/S, Kraftværksvej 53, 7000 Fredericia, Denmark

Accepted 2023 December 14. Received 2023 December 5; in original form 2023 May 11

SUMMARY

Unexploded ordnance (UXO), often deployed in WWI and WWII, are still present on the seabed posing a risk to seabed construction. UXO surveys identify potential UXO targets which are then investigated and removed where necessary; however, approximately 96 per cent of targets investigated on projects included in this study were non-UXO (false positives). Here we investigate methods of improving statistical confidence in targets picked through the improved classification of magnetic response, utilizing simulation methods and historic data. A simulation of the induced magnetism of UXO was developed to model the most likely dimensions and orientation of a given source item. Modelling results and measured variables were combined in an optimization algorithm, hereon referred to as ‘the classifier’. We document the results of integrating the magnetic responses of 3027 targets from 18 offshore wind projects into the classifier. Five of these projects were performed as tests in which the target results were unknown during classification. Finally, the classifier was deployed on a live project, Hollandse Kust Zuid 3 and 4 Offshore Wind Farm, in which it enabled the removal of 67 targets from the 1200-target investigation list. The classifier proved to be a valuable additional tool to assist the target rationalization process, reliably and repeatably distinguishing UXO from other items, thereby reducing false positives and repeatably demonstrating no threshold UXO false negatives. Assumptions and limitations of this methodology were highlighted, which must be understood and considered when integrating this approach on future projects.

Key words: Magnetic anomalies; modelling and interpretation; Inverse theory; Statistical methods.

1 INTRODUCTION

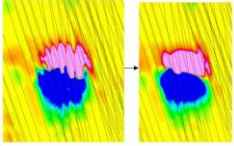
1.1 Survey industry

Many unexploded ordnance (UXO) deployed in WWI and WWII are still present on the seabed with an estimated 1.3 million tonnes of UXO remaining in the German Bight and approximately 0.3 million tonnes in the German waters of the Baltic Sea (Böttcher *et al.* 2011; Fraunhofer ICT 2018). The threat of encountering UXO must therefore be considered before installing offshore wind-farms and cables. An offshore survey for UXO usually comprises a magnetometer or gradiometer dataset supported by sidescan sonar, multibeam and sometimes high-resolution sub-bottom-profiler datasets. The number of targets for inspection produced

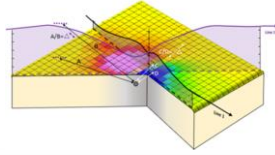
from these datasets substantially impacts the cost and effectiveness of the UXO investigation campaigns which follow, with approximately 4 per cent of potential UXO targets picked from the projects included in this study resulting in a positive UXO identification. The target investigation phase of a UXO project, with inspection of individual targets, is more expensive than the initial UXO survey phase covering data acquisition over an area. In a financial review of UXO operations within the German North Sea, for projects undertaken outside of known UXO dumping areas, survey costs represented on average 15 per cent and identification and clearance operations 85 per cent of the total costs (Sinclair 2020). This highlights a need for research and development in target rationalization and its consequent reduction in the clearance scope.

Methods

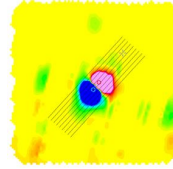
1 Manual QC



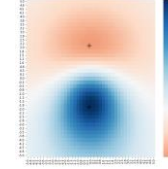
2 Normalisation



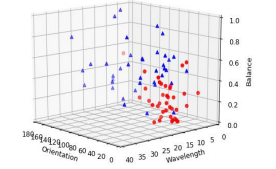
3 Data extraction



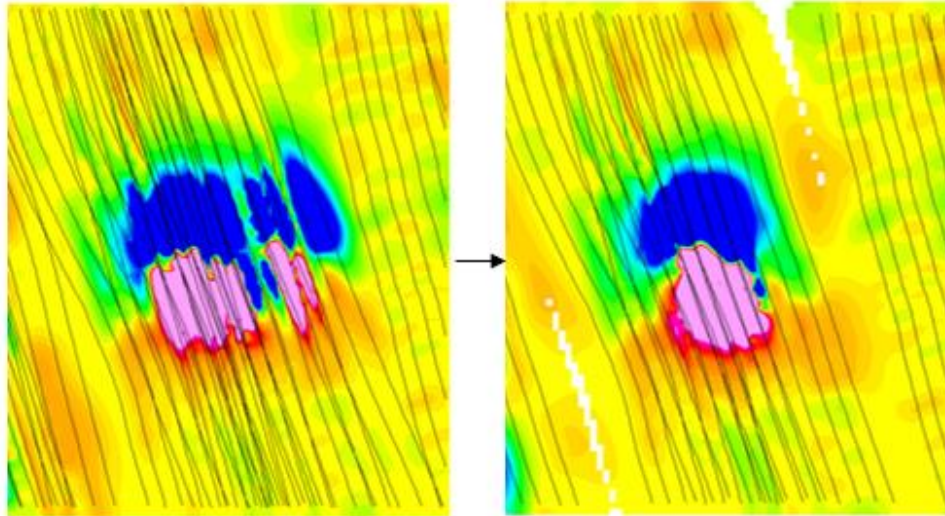
4 Simulation



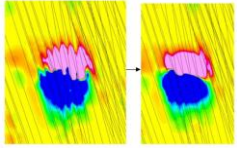
5 Optimisation



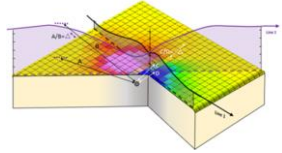
- Classification possible for 98% targets



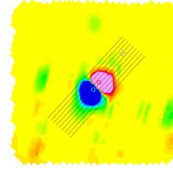
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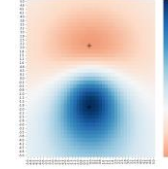
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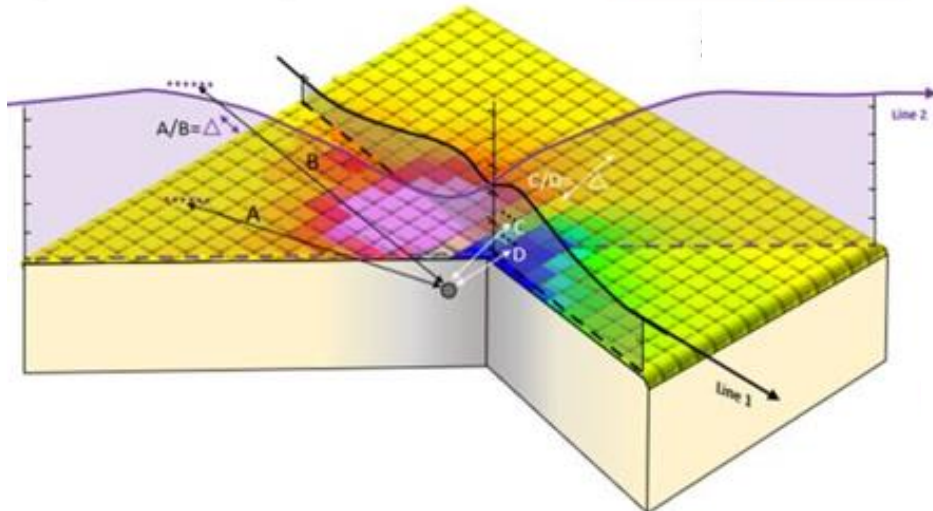
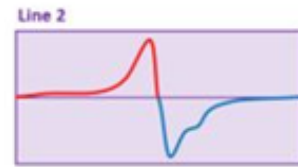
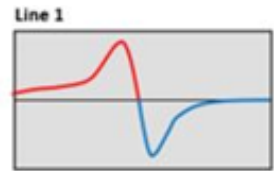
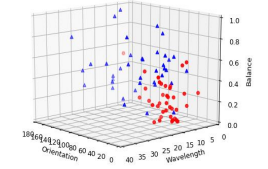
3 Data extraction



4 Simulation

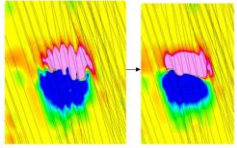


5 Optimisation

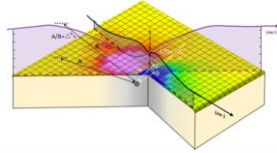


- All data processed with the same filters

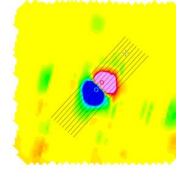
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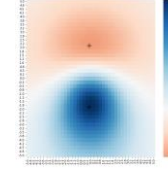
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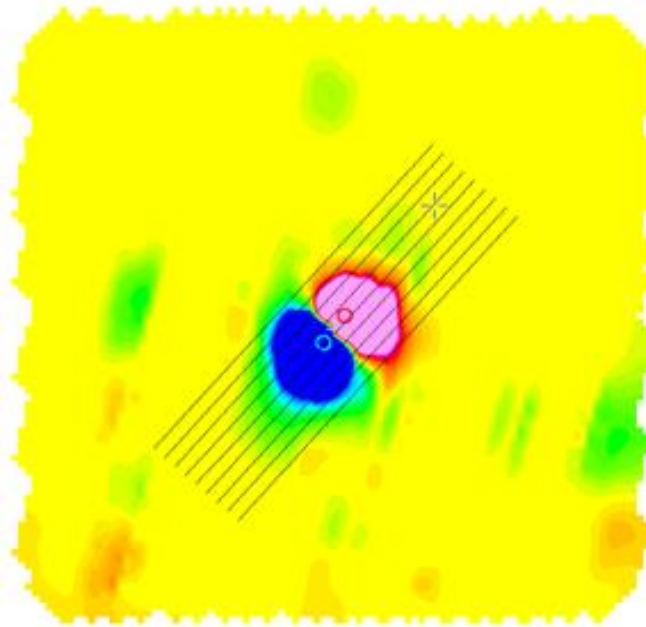
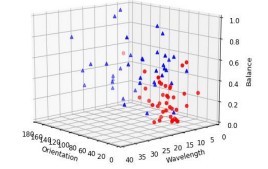
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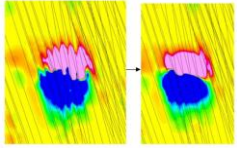


5 Optimisation

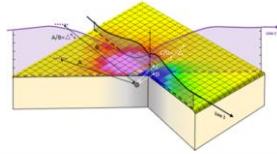


- Industry focus is on target size
- Classifier focus is on target shape
- 85 variables extracted per target

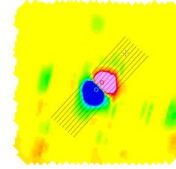
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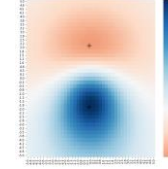
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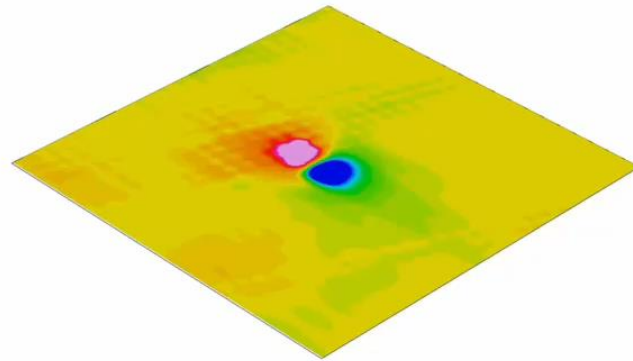
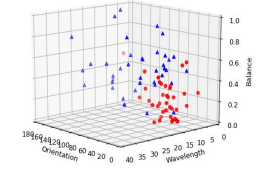
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4 Simulation

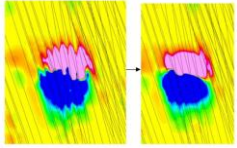


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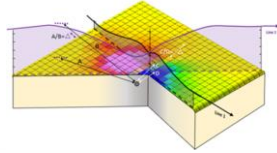


- Replicate the target response
- Modelled sphere
- Aspect ratio
- Declination
- Item diameter

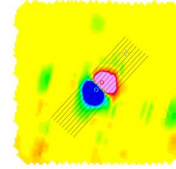
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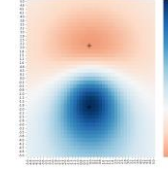
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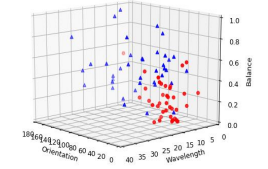
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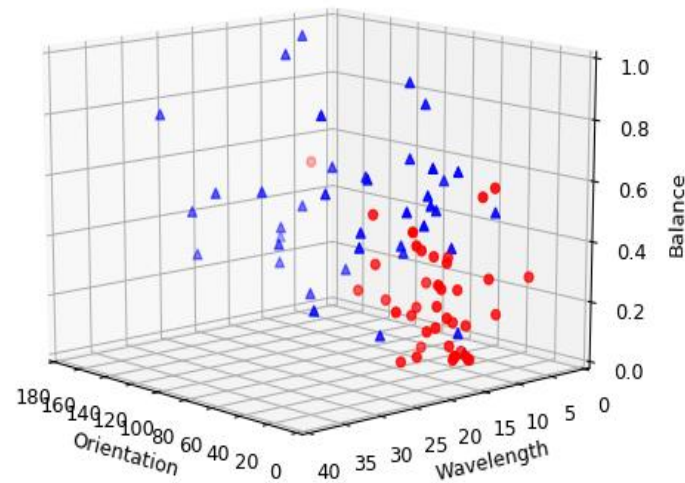
4 Simulation



5 Optimisation



- UXO
- ▲ False positives



- Optimisation ranking algorithm
- Combining many variables

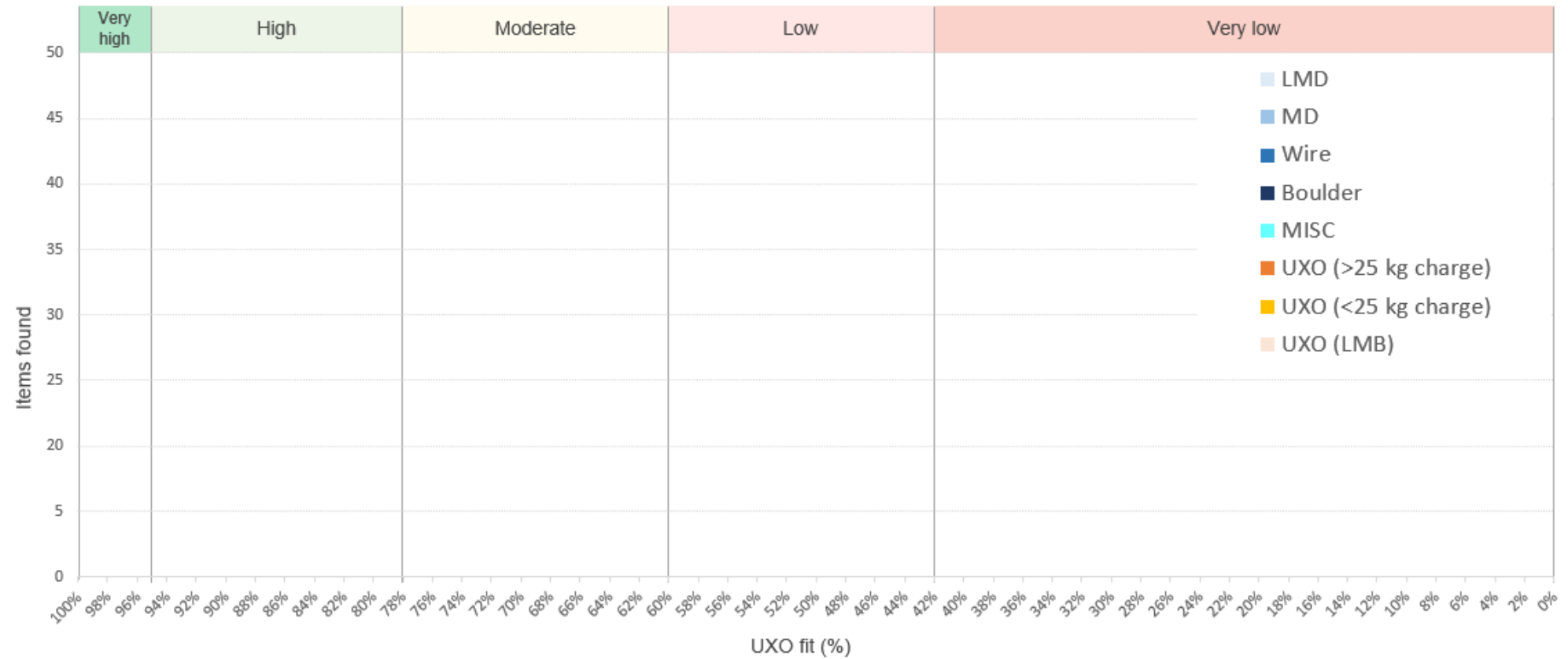
Outputs

- UXO fit value
- UXO fit category

Results

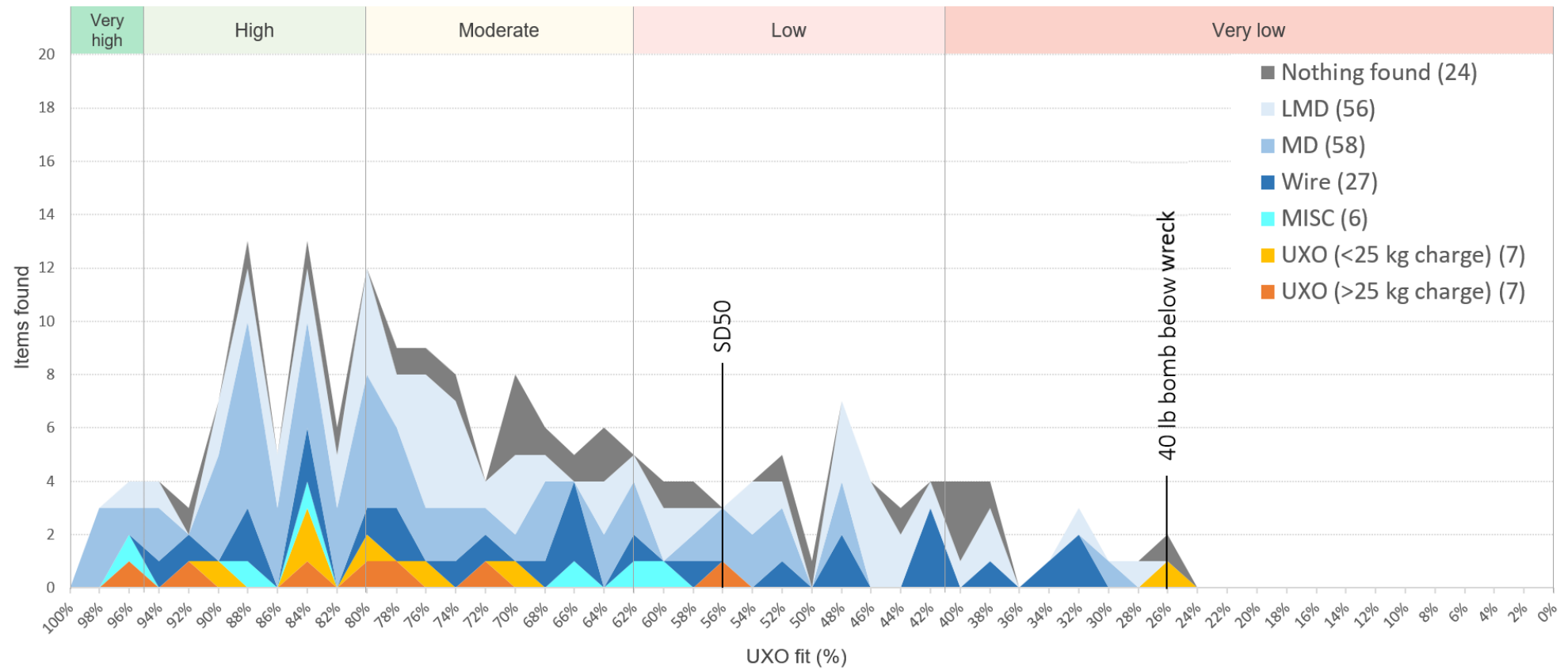
Results – graphs explained

- 5 test projects
- 1 live use project



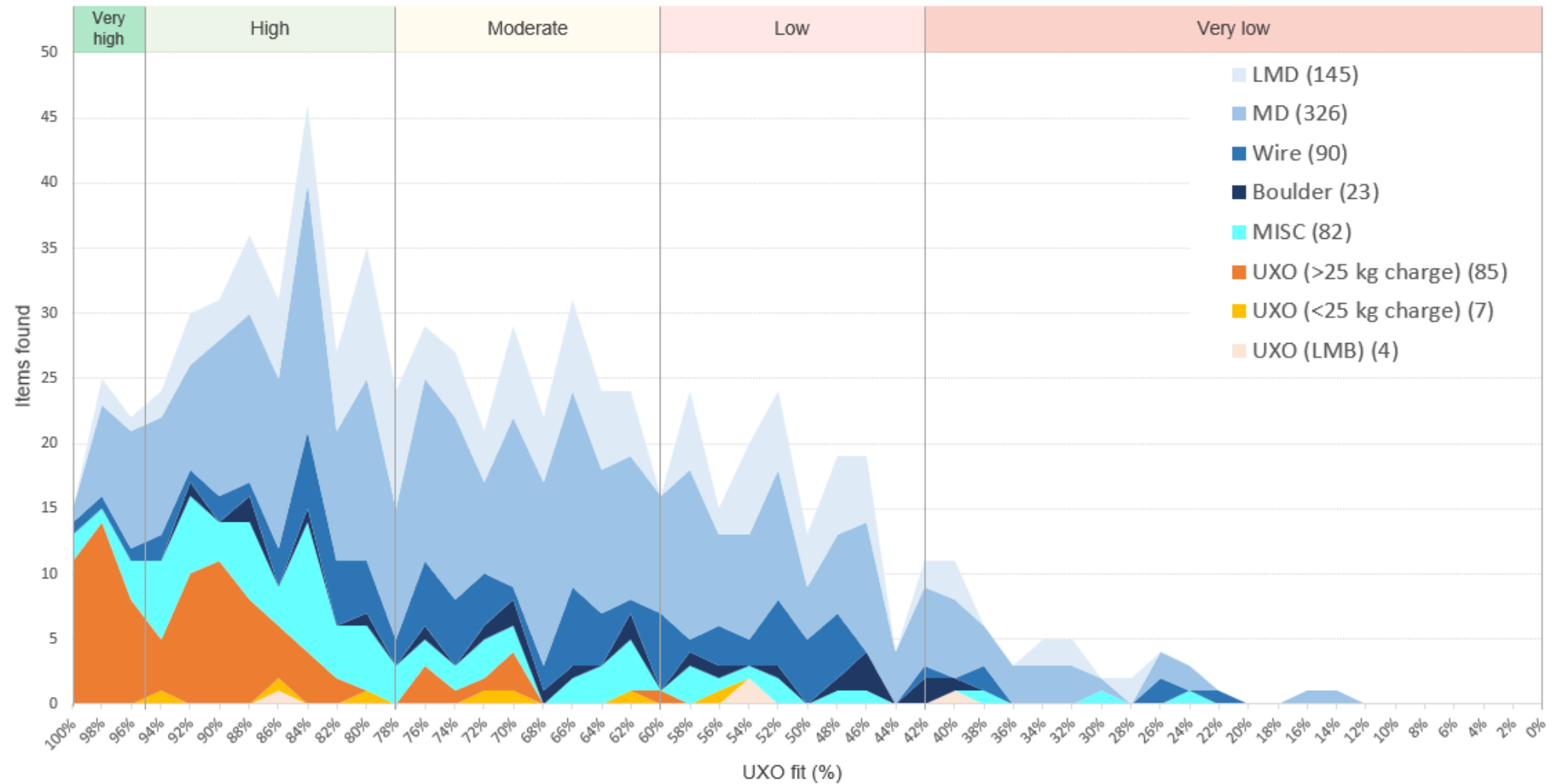
Results – First live test project

- Classifications performed before target investigation



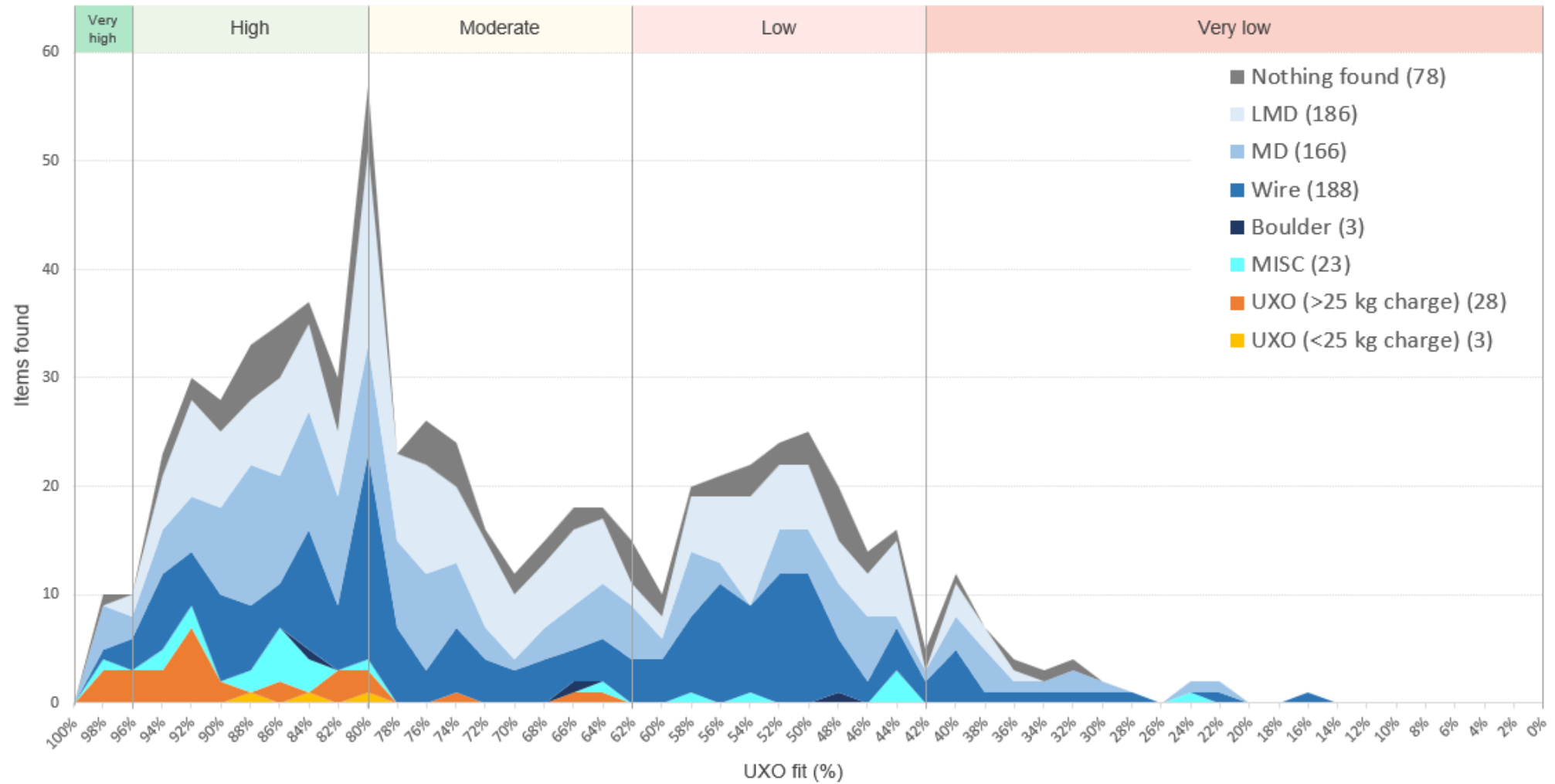
Results – 3 x test projects

- Classifications performed with no knowledge of what each target was

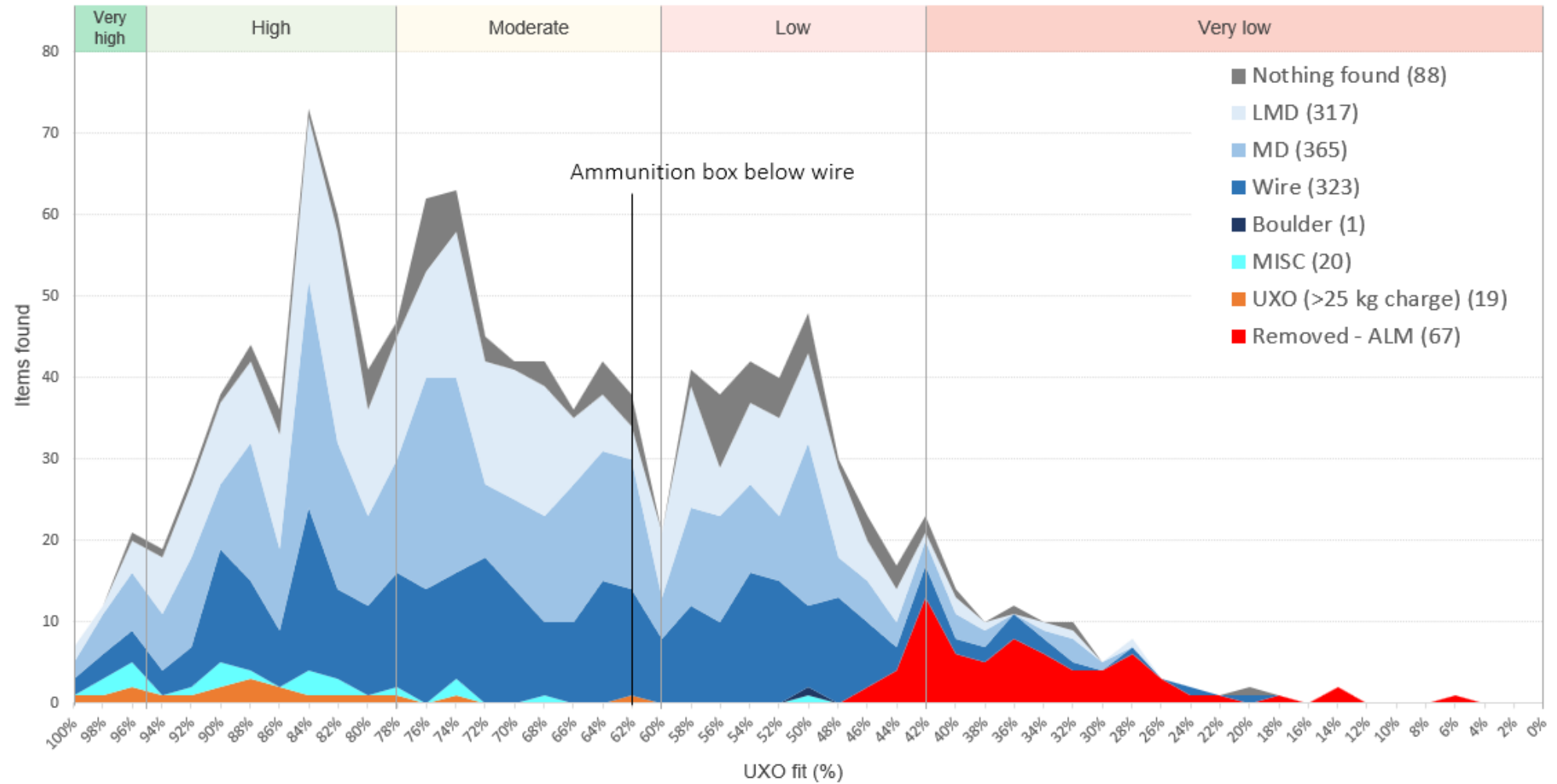


Results – Live test project

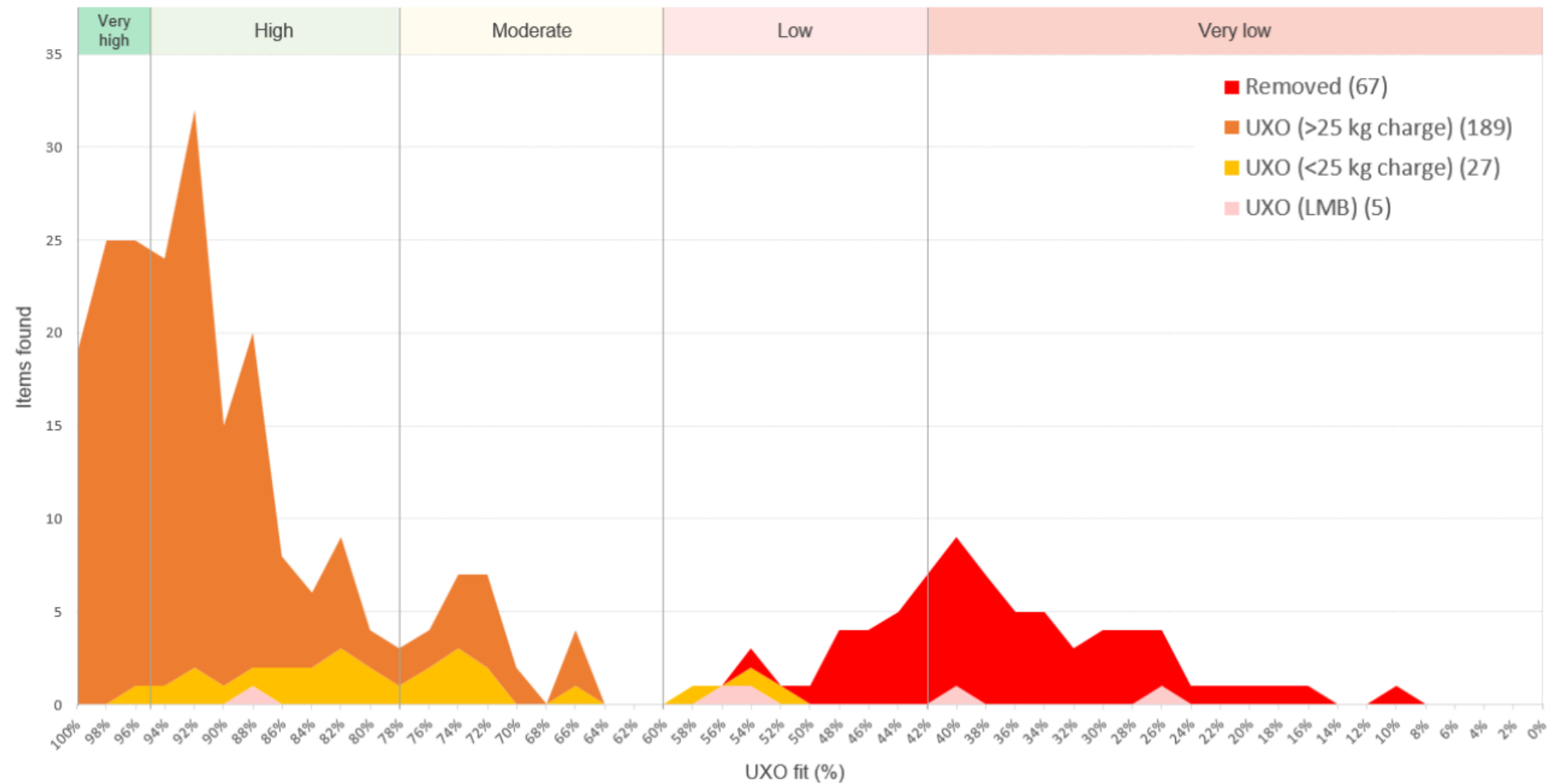
- Classifications performed before target investigation



Results – Live project use



Results – Combined



Conclusions

Conclusions

- Separated all threshold UXO from 36.8% debris
- ~8% target reduction on projects
- Saved ~11 IDC vessel days
- Additional statistical confidence

Limitations

- Trained on North Sea data
- Overlapping responses – magnetics limitation
- LMB mines not included
- Estimated burial depth
- Simulation does not consider remanent magnetism
- Assumed horizontal orientation

Final verdict

- To be used alongside other datasets and outputs
- Additional tool in the toolbox
- Provides a level of confidence never seen before in the marine UXO survey industry

What next

- Making target classification available to everyone
- Accessible through Oasis Montaj
- Add more UXO to the library
- Improve on the optimisation algorithm – reduce the potential for overfitting
- Integrate machine learning tools

Questions