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Digital image-based Area/Weight-Models improve weight estimates of important North Sea fish

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Summary
Rapid development of digital imaging and subsequent processing hard- and software makes new information accessible to research. Pictures or video footage can be used to estimate weight of individual fish if underlying species-dependent relationships of geometric measures are known. For this purpose Whiting (*Merlangius merlangus*) were individually measured, weighed and photographed during July/August 2014. A logarithmic power model log(Y) = log(a)+b*log(X) was used to estimate weight from total visible area. Fit was high ($R^2>0.99$) and the model showed strong performance (mean deviation 0.42g +/- 4.2 Std) when tested against previously measured Whiting from Winter 2013/2014. Our results show that with an Area/Weight-Relationship it is possible to accurately estimate weight of individual Whiting (and other species) from digital images with advantages over traditionally used Length/Weight-Relationships. Applications range from conveyor belt analysis on board of commercial or fisheries research vessels to continuous video based monitoring of MPAs or ROV video footage.

Introduction
Stock sizes of various commercially and ecologically important fish species are fluctuating over a broad range for party unknown reasons. Yet data for fisheries research taken on board of vessels traditionally consists mostly of one-dimensional length measurements of individuals, omitting other important information. With rapid development of digital imaging, storage devices and the power of artificial neural networks for subsequent analysis, additional information becomes available and accessible to research. HD-Stereo-Cameras allow extraction of size information from pictures or video footage, if underlying species-dependant relationships are known. However, although regularly used in agricultural science (e.g. Schofield 1990) Area/Weight-Relationships are sparse for fish (Zion 2012). Given total visible area as input, we developed a model that can accurately estimate individual weight of North Sea Whiting (*Merlangius merlangus*).

Materials and Methods
In July and August 2014 randomly selected Whiting (n=257) were carefully dried using tissue paper and measured for total length (TL, 0.1cm) and weighed (0.1g) during cruise 691 of the German Research vessel FFS Solea. Sizes of specimens were equally distributed across eleven size classes. Pictures of each specimen were taken using a tripod-mounted Canon EOS 650D (18-55mm Canon lens) and an Artograph Light Pad A950 with attached scale (14.95cm). Pictures were processed with Adobe Photoshop CS3 (http://www.adobe.com) and visible area (VA) of each fish was calculated using ImageJ (http://imagej.nih.gov/ij/) without excluding fins or tails (following Balaban et al. 2010). Using SAS 9.4 (http://www.sas.com) all measurements were log-transformed and a logarithmic power model was used to estimate weight from visible area as followed: log(W)=log(a)+b*log(VA) with W=individual estimated weight, VA=total visible area and a and b being parameters. The model was tested using Whiting (n=174) measured and weighed during cruises 682 and 683 of FFS Solea in November/December 2013 and January 2014, respectively. Quality of fit was calculated by mean deviation of estimated from measured weight.

Results and Discussion

TL and Weight of Whiting used for model calculation ranged from 4.8 to 39.9 cm and 0.8 to 528.4 g, respectively. Whiting for model testing ranged from 15.0 to 30.3 cm and 26.0 and 283.0 g. Table 1 shows parameter estimates. The logarithmic power model (Figure 1) shows a high fit ($R^2 > 0.99$). Mean deviation of the model to measured weights of test Whiting was 0.42g +/- 4.2Std. This shows that Area/Weight-Models, with their two-dimensional nature, might also be able to cope with problematical differences of weight estimates in directly neighbouring stocks of the same species arising from one-dimensional Length/Weight-relationships (Gerritsen and McGrath 2007). Thus one parameter set might be sufficient for different stocks of one species and even for different seasons in the course of a given year. This study was the first one applying this approach to North Sea Whiting. However, logarithmic power models were also tested for additional species including Cod (*Gadus morhua*) and Haddock (*Melanogrammus aeglefinus*) and give similar levels of performance. Combined with artificial neural networks, possible applications of Area/Weight-Models include automated analysis of conveyor belt video footage taken on board of commercial or fisheries research vessels. However, with the possibility of continuous monitoring of MPAs and wind park sites or ROV video footage, new future tasks arise, like concluding data from different more or less complex geometric dimensions or patterns to measures of weight, volume or even age.

Table 1: Parameter estimates for the logarithmic power model

Parameter	Estimate	StdErr	Alpha	LowerCL	UpperCL	tValue	Probt
a	0.1675	0.00148	0.05	0.1646	0.1704	113.45	<.0001
b	1.4771	0.00231	0.05	1.4726	1.4816	640.05	<.0001

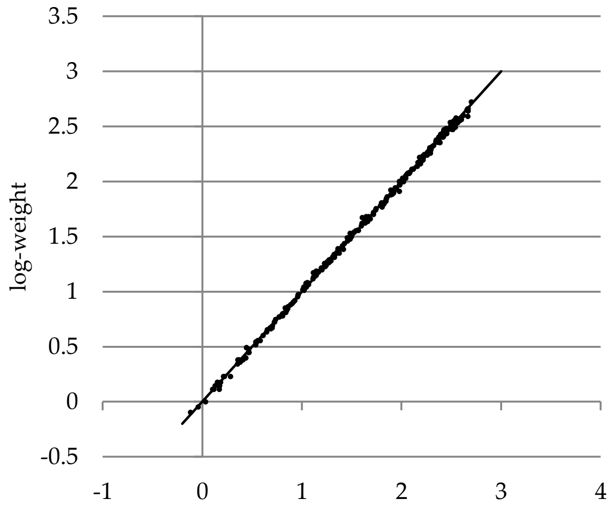

Figure 1. Logarithmic predicted weight (x-axis) against logarithmic measured weight (y-axis). Solid Line represents a slope of 1.

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