SEALION ENGINEERING

* Estimating the effect of fouling in ship performance based only on observed hull condition

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INTRODUCTION

- In the era of decarbonization, the need for vessel's performance monitoring is more important that ever.

- The main tools in order to improve vessel's performance (hull & propeller performance)
  - noon reports (low-frequency data)
  - data from sensors (high-frequency data)
  - "in-voyage speed tests" (manual measurements or from sensors)
  - pro-active underwater inspection plan.

INTRODUCTION

During an underwater inspection:

- Vessel has usually limited time at port (or anchorage). Therefore, decisions regarding whether to proceed with hull cleaning or not shall be made quickly based on a brief description of findings and a few representative underwater photos.

- The expert assesses the condition of the hull and decides next actions (full or partial hull cleaning, propeller polishing, no action etc.). He/she must also confidently provide an estimation of the power/fuel consumption and ensure that Charter Party obligations are met.

INTRODUCTION

If a vessel is closely monitored, then usually there are no surprises. The expert knows more or less what to expect and relevant hull/propeller cleaning actions have already been pre-decided based on the available data.

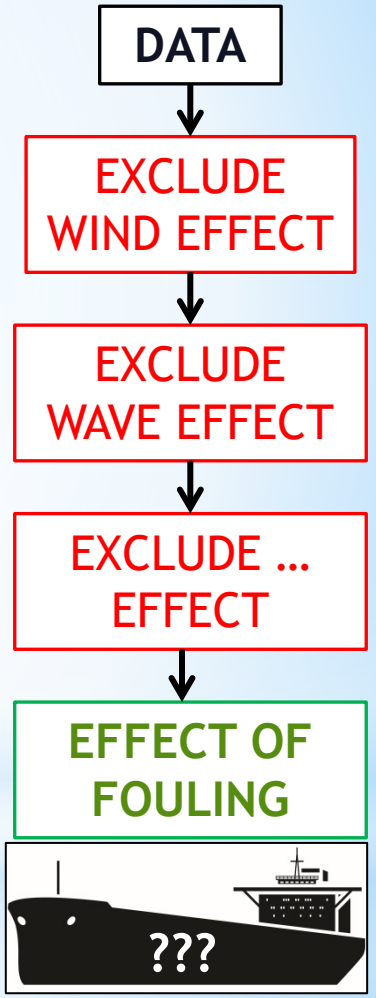
However, sometimes there are certain obstacles such us:

- Lack of high-frequency data (Vessels without sensors)
- Reliability of noon reports can many times be questionable
- Limited available data in the examined period (bad or unsteady weather, unsteady course, varying speed, frequent changes in Power/RPM)
- Sensor malfunction

In such cases, more caution is needed during the underwater inspection. The decision making process regarding hull cleaning depends heavily to the experience of the performance expert rather than a prior conducted analysis. **What tools can the expert use in order to be more confident about his/her decision?**

CONCEPT

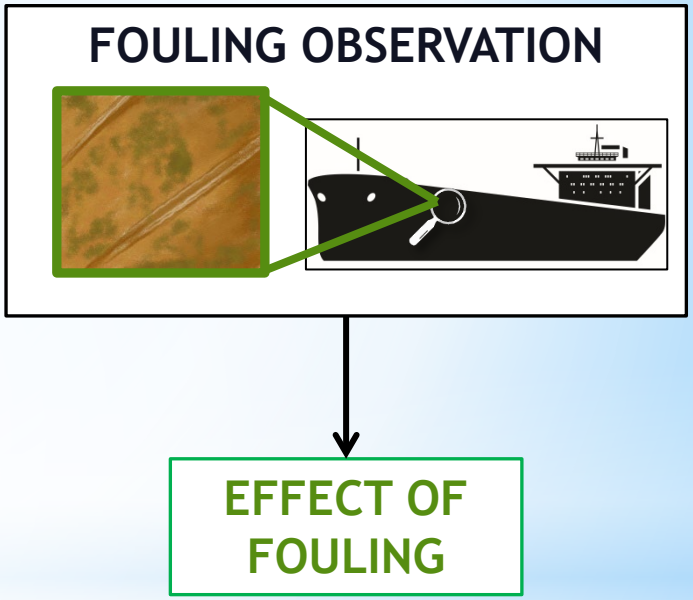
- Commonly, the impact of hull fouling in ship performance is assessed **indirectly** by using sensor data. This approach requires the isolation of various factors such as the effect of wind, waves, shallow waters etc. to discern the residual effect of fouling.
- Despite the fact that this indirect approach is effective and common practice, it still **treats fouling as a "black box"** and the effect in performance is indirectly estimated instead of directly assessed based on what is actually present at the hull.



*CONCEPT

* What if we approach the effect of fouling in vessel performance **directly** and assess what is actually present at the hull right now?

* This approach can provide **instant** and **cost-effective** estimation of added power and fuel consumption based solely on observed hull condition, offering an initial estimation which is not affected by poor reporting, lack of "good quality" data, weather effect, sensor malfunctions/miscalibrations etc.



CONCEPT

* **"Ship Performance Assessment Based on Observed Fouling"** is a semi-empirical method that provides instantly a rough estimation of the effect of fouling in ship performance by using only the observed condition of the hull (as provided by the divers during an in-water survey).

Visual Inspection (In-water survey)

Sensor Data / Noon Reports / Speed tests

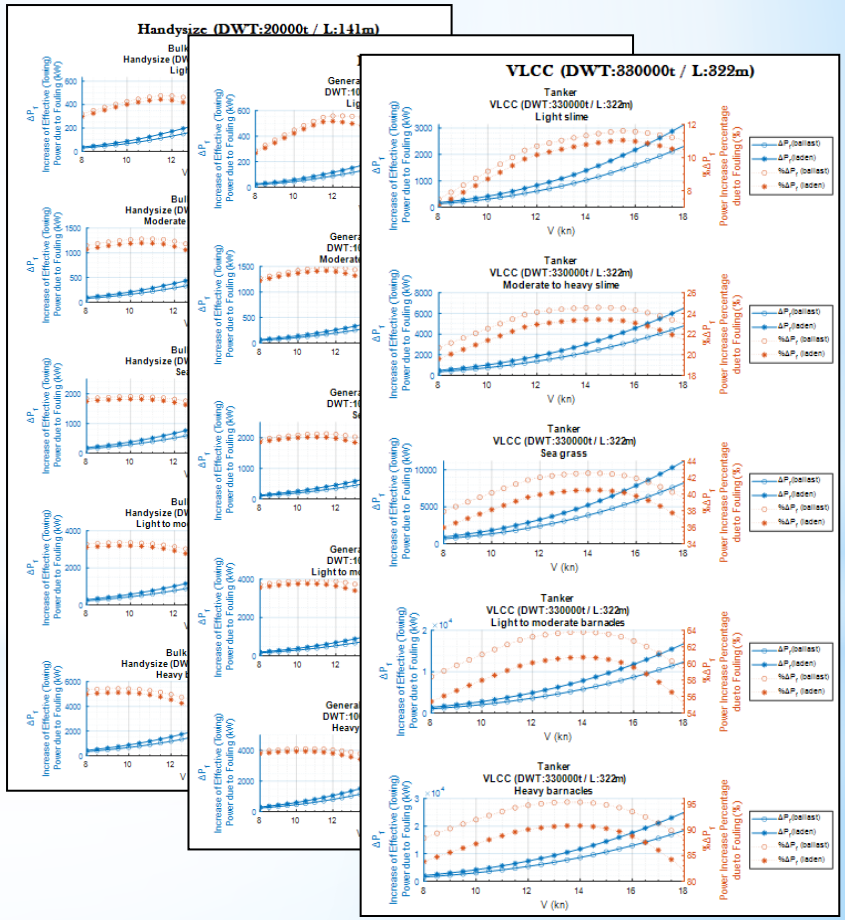
Performance Prediction

Action (e.g. Hull Cleaning)

*DEVELOPMENT

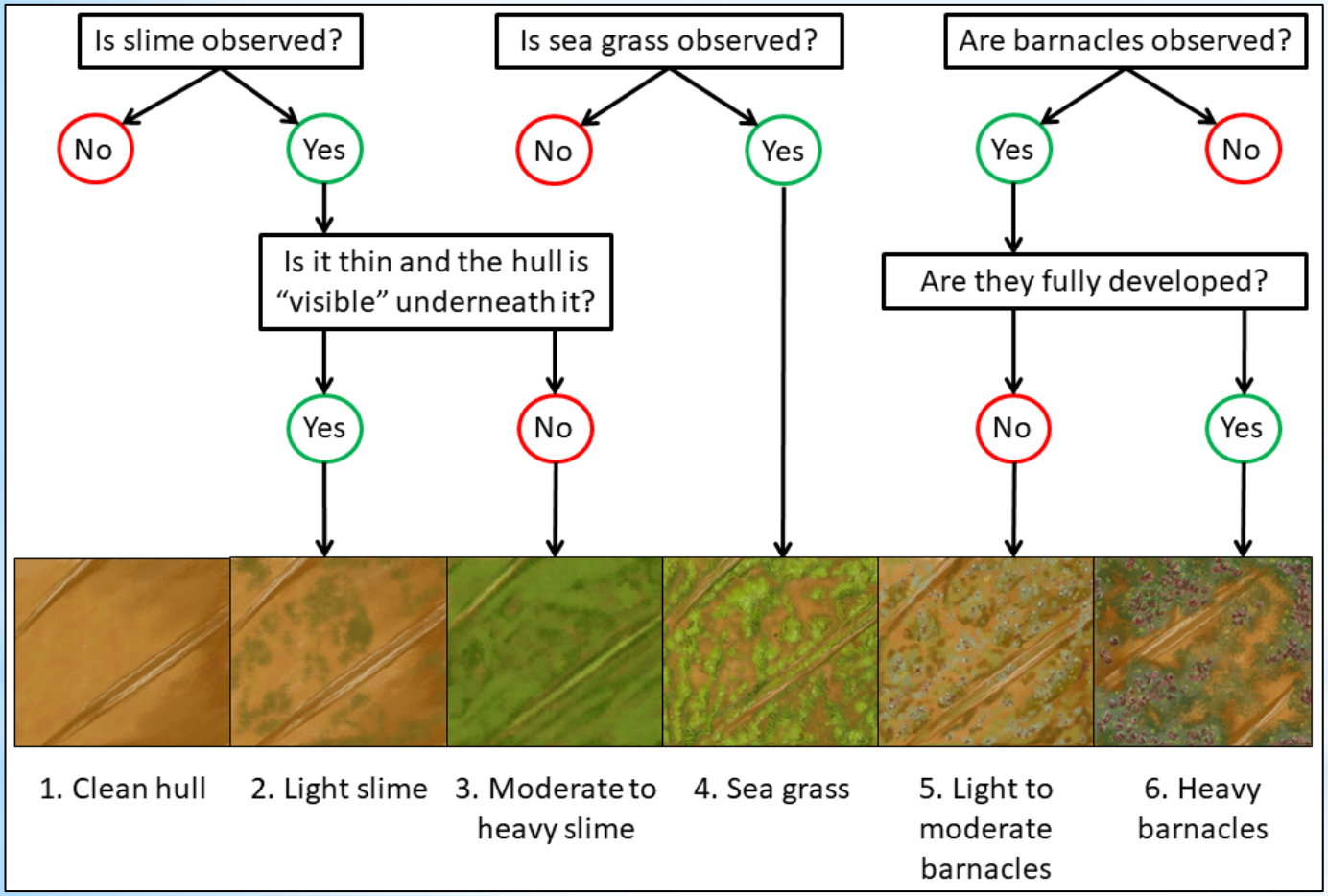
The book is divided in two parts:

* Methodology Description with examples and a case study.
* 480 fouling diagrams for a wide range of vessel types & sizes



DEVELOPMENT

How are the fouling diagrams generated?



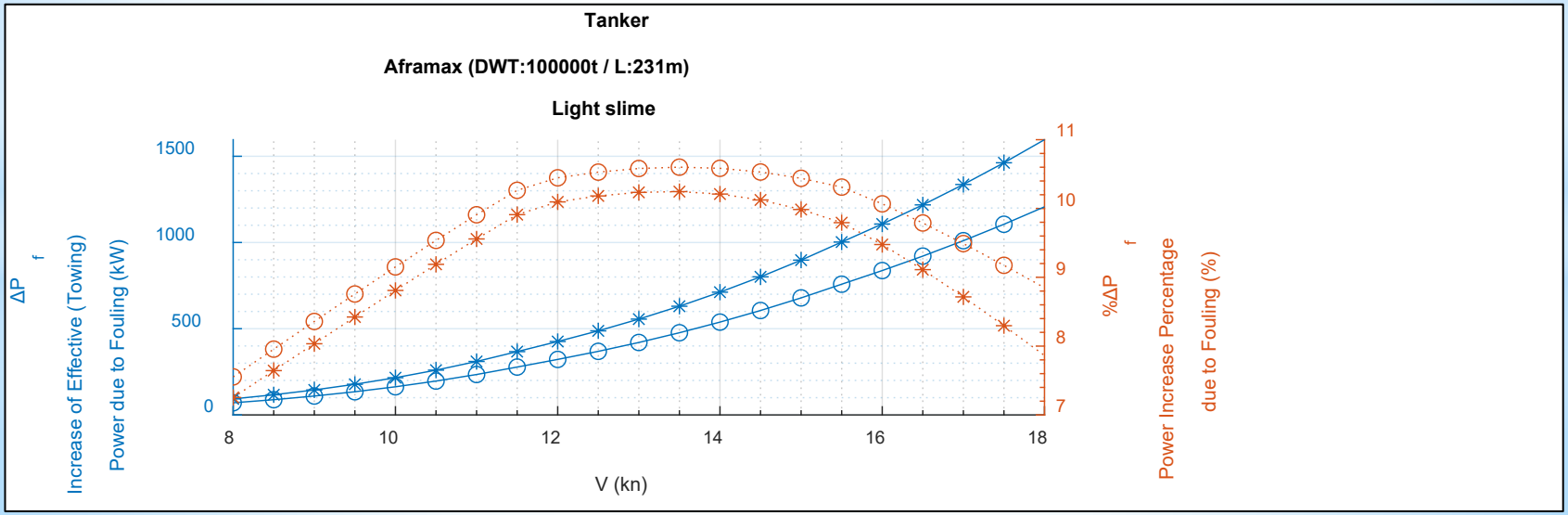
- Initially, fouling is divided in 6 different categories with increasing severity.
- Each fouling category has a hull roughness value assigned.
- Based on this roughness, we calculate the effect of each fouling category in the frictional resistance coefficient (ΔC_F) along with the effect in total power.
- The result of the above is the generation of a library of fouling diagrams with the effect of each fouling category in the performance of a vessel.

DEVELOPMENT

* There are 5 fouling diagrams for every vessel type and size (one for each fouling category)

1. Light Slime
2. Moderate to Heavy Slime
3. Sea Grass
4. Light to Moderate Barnacles
5. Heavy Barnacles

* Fouling diagrams provide the increase of effective power due to fouling in Kw [left] and percentage-wise [right] for ballast and laden condition, for different speeds. They refer to 100% of fouling coverage.



DEVELOPMENT

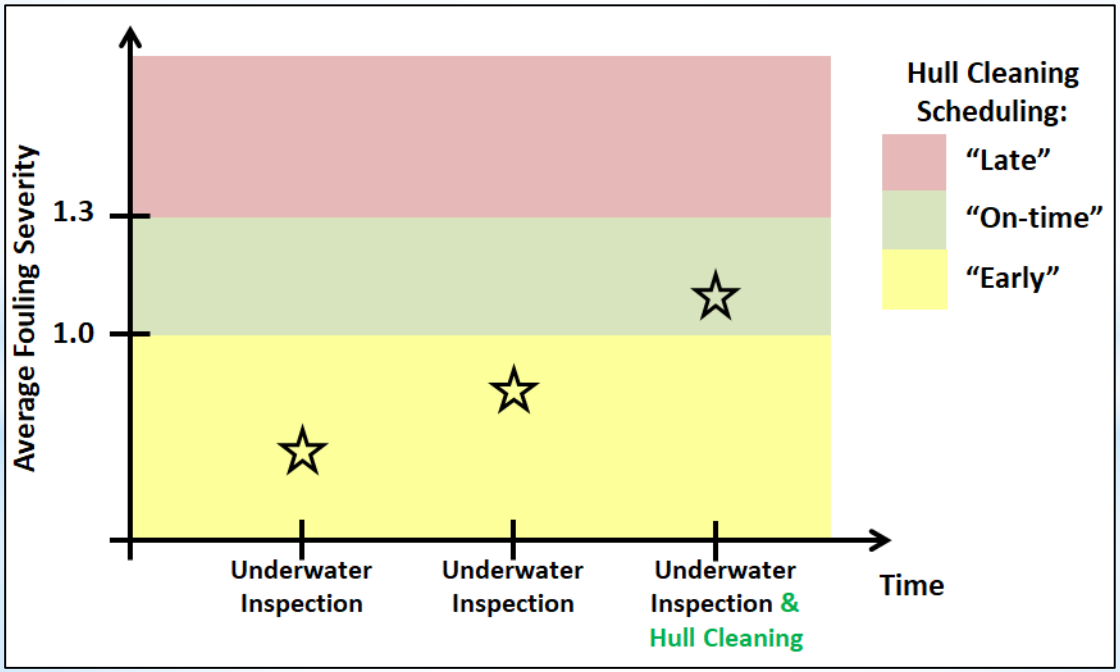
Fouling diagrams included in the book for:

* Tankers (2,000 to 330,000 t DWT)
* Bulk Carriers (1,000 to 330,000 t DWT)
* General Cargo Ships (2,000 to 45,000 t DWT)
* OBO Carriers (60,000 to 160,000 t DWT)
* Containerships (400 to 12,000 TEU)
* LNG Carriers (125,000 to 260,000 m3 Capacity)
* RORO Ships (500 to 5,000 Lanemeters)
* RORO/Passenger Ships (70 to 200 m Length)
* Chemical Carriers (5,000 to 50,000 t DWT)
* Reefer Ships (2,500 to 18,000 m3 Capacity)

DEVELOPMENT

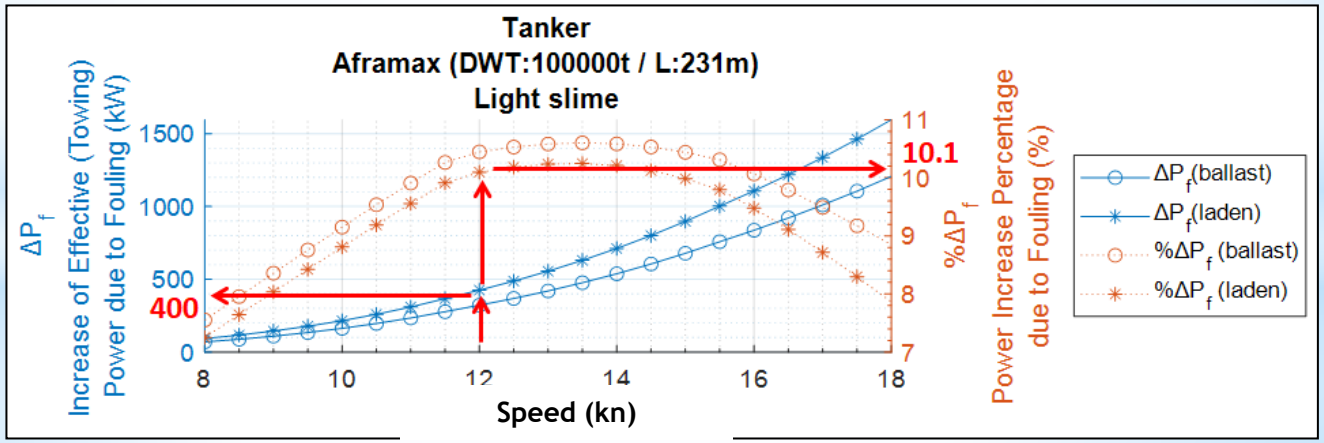
The fouling diagrams allow us to estimate four valuable KPIs for assessing hull performance:

- Average Fouling Severity
- Power Increase Percentage due to Fouling
- Added Brake Power due to fouling
- Added Fuel Consumption due to fouling



*APPLICATION

*Example:



$\Delta P_{f-light\ slime} = +400\ kW$

$\%\Delta P_{f-light\ slime} = +10.1\%$

APPLICATION

* Example:

* Estimated Added Brake Power due to Fouling:

$$\Delta P_B = \frac{\Delta P_{f-light\ slime}}{\eta_T} = \frac{\mathbf{400}}{0.7} = \mathbf{+571kW}$$

* Estimated Added Consumption due to Fouling:

$$\Delta FC_f = \frac{SFOC}{10^6} \cdot \Delta P_B \cdot 24 = \frac{170}{10^6} \cdot 571 \cdot 24 = \mathbf{+2.3\ t/day}$$

APPLICATION

* What about more complex cases?

Different types & percentages of fouling between verticals and bottom

SPREADSHEET

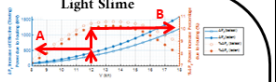
DETAILED STEP BY STEP INSTRUCTIONS INCLUDED IN THE BOOK

STEP 1

Find the diagrams in Appendix B that refer to your ship type and size and read the values of each fouling category (for all 5 types of fouling), for the desired operational speed

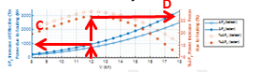
$\Delta P_{f-light\ slime} = A$ $\quad \%\Delta P_{f-light\ slime} = B$

Light Slime



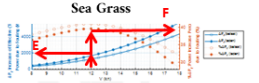
$\Delta P_{f-moderate\ to\ heavy\ slime} = C$ $\quad \%\Delta P_{f-moderate\ to\ heavy\ slime} = D$

Moderate to Heavy Slime



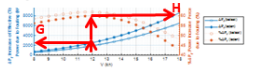
$\Delta P_{f-sea\ grass} = E$ $\quad \%\Delta P_{f-sea\ grass} = F$

Sea Grass



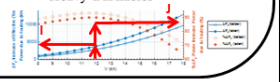
$\Delta P_{f-light\ to\ modrate\ barnacles} = G$ $\quad \%\Delta P_{f-light\ to\ moderate\ barnacles} = H$

Light to Moderate Barnacles



$\Delta P_{f-heavy\ barnacles} = I$ $\quad \%\Delta P_{f-heavy\ barnacles} = J$

Heavy Barnacles



STEP 2

Calculate KPIs

ACCURACY

* Available data from 10 vessels (Tankers & Bulk Carriers)

* The initial validation's results indicate an average deviation close to ±10% (compared with sensor data). This refers to the expected accuracy of the estimated added power (ΔPB) and added fuel consumption (ΔFOC)

* Further validation remains to be conducted in due course.

*SEALION PERFORMANCE REPORT

The concept of the book led us to create our **premium** product.

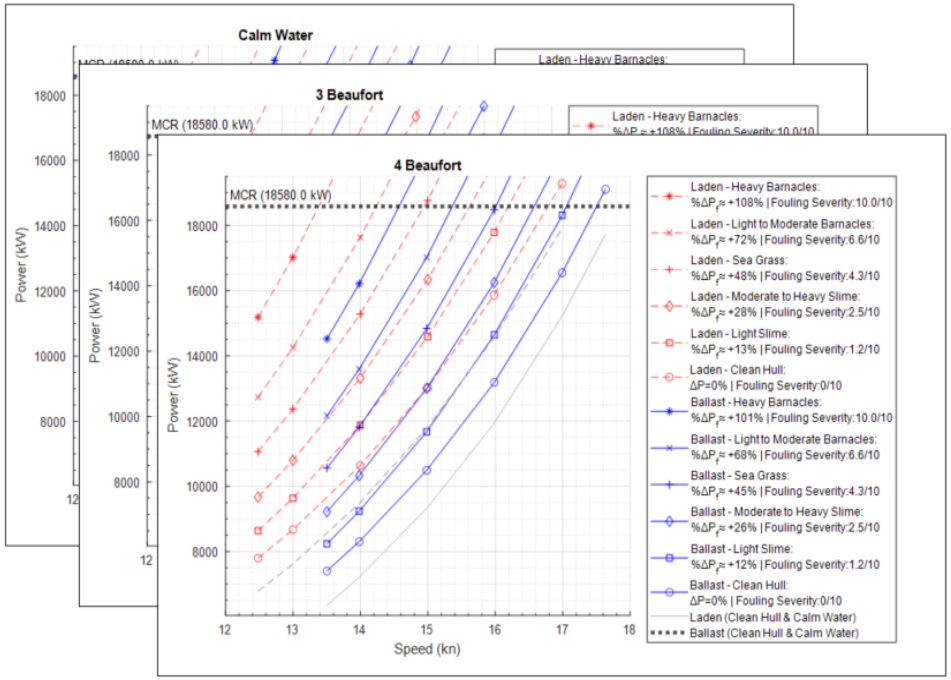
We call it "**Sealion Performance Report**" and it incorporates the developed methodology with a vessel-specific performance profile.

In the "**Sealion Performance Report**" we combine vessel drawings and technical files to create an one-off (one report for the whole life cycle of the vessel), ship-specific report that includes:

- ✓ Tailor-made fouling diagrams based on each vessel's unique characteristics
- ✓ Detailed performance profile tables (Speed/Power/RPM/Consumption) for different loading conditions, weather conditions (ISO 15016 - "Wind Resistance Coefficients" & "STAWAVE-1") and fouling types/percentages

SEALION PERFORMANCE REPORT

* The result is a unique toolbox that utilizes hull observations and/or operational data to have in hand a high quality and complete initial performance prediction for your vessel.



0B | Laden | Fouling Severity:0/10 | %ΔPf≈+0%

3B | Laden | Fouling Severity:0.6/10 | %ΔPf≈+6%

4B | Laden | Fouling Severity:1.2/10 | %ΔPf≈+13%

V (kn)	P (kW)	RPM	Fuel Cons. (t/day)	Fuel Cons. (t/nm)
12.5	8638.3	68.1	38.3	0.1279
13.0	9634.8	70.8	42.5	0.1363
14.0	11875.9	76.3	52.0	0.1547
15.0	14588.8	82.2	63.4	0.1761
16.0	17782.7	88.2	79.1	0.2062
-	-	-	-	

CONCLUDING REMARKS

* A methodology for predicting the effect of fouling in ship performance with no other information other than brief description of findings from divers and/or some representative photos from an underwater hull inspection has been developed.

* It should be stressed out that the **visual aspect is an inseparable part of vessel performance**, so vessel performance based on observed fouling comes to accompany existing standard performance practices resulting to a more **holistic approach to vessel performance monitoring.**

Thank you!

* You can **download a free demo of the book** and find out more information about our vessel performance services at:

www.sealionengineering.com