Protocol to quantify the Level of Fouling (LoF) on vessel hulls using an ordinal rank scale

Introduction and background

A considerable proportion of private and commercial yachts and ships carry assemblages of marine sessile organisms ("fouling organisms") on their hulls. In the case of international vessels, these assemblages may contain non-indigenous species that should be prevented from becoming established in New Zealand. It is therefore important to have techniques to quantify both the proportion of vessels that carry fouling as well as the abundance of fouling organisms on individual vessels.

The fouling rank scale described on the following pages was first developed in 2002 to provide and evaluate an efficient method for estimating Levels of Fouling (LoF) on international yachts entering New Zealand. The rank scale, which ranges from 0 (no fouling) to 5 (very heavy fouling) and is used by a surface observer without getting in the water, was calibrated against *in situ* sampling of the same yachts. Despite considerable variation in the distribution and abundance of fouling assemblages on yachts within the various ranks, the LoF ranks allocated by a surface observer were found to be representative of the actual amount of fouling on the hulls, including areas that can not be seen from the surface. A manuscript describing and evaluating this approach (Floerl, Inglis and Hayden) has been submitted to the journal *Environmental Management* and is currently (July 2004) in review.

Contents of this protocol

I. Allocation of LoF ranks from above the water surface

In most port and marina environments visibility under water is approximately 1 m. This and the fact that boat and ship hulls tend to curve inwards makes it impossible to see hull-fouling assemblages in detail from the surface, except for those areas associated with or up to ~ 75 cm below the waterline. Areas of interest that can be seen by a surface observer (standing on the dock or in a boat next to the vessel of interest) include (Fig. 1):

    (i)   bow,
    (ii)   waterline,
    (iii)   hull area below the waterline, and
   (iv)   stern and rudder

For small vessels such as yachts and fishing boats (generally < 15 m in length) the surface observer should visually inspect all of these areas, and *allocate a combined LoF rank* based on the criteria listed in Table 1. For large commercial ships it may be practical to allocate separate ranks for the three different target areas and calculate their average. However, the relationship between average LoF ranks and the abundance and diversity of hull-fouling assemblages across the whole hull has so far not been assessed.
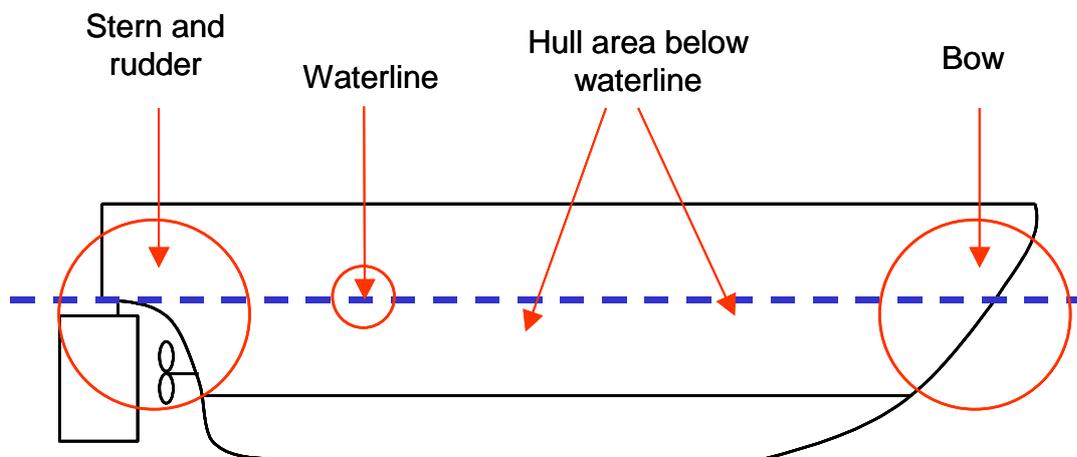
Fig. 1: Target areas on a vessel hull to estimate LoF ranks by surface observation (above-water).

Table 1: Criteria for allocating LoF ranks by visual inspection from above the water surface.

LoF rank	Criteria
0	No visible fouling. Hull entirely clean, no biofilm (slime) on any visible submerged parts of the hull.
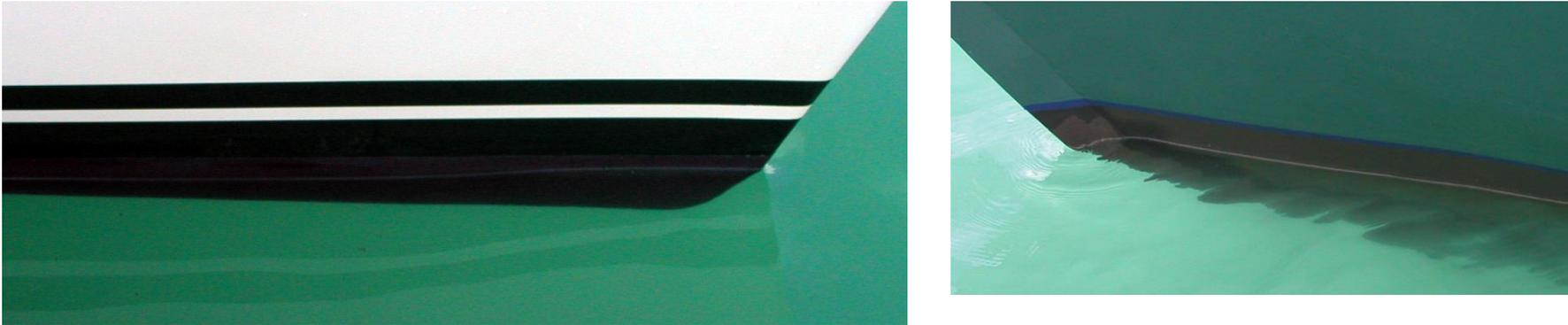
| 1 | Hull partially or completely covered in slime fouling. Absence of any macrofouling. |
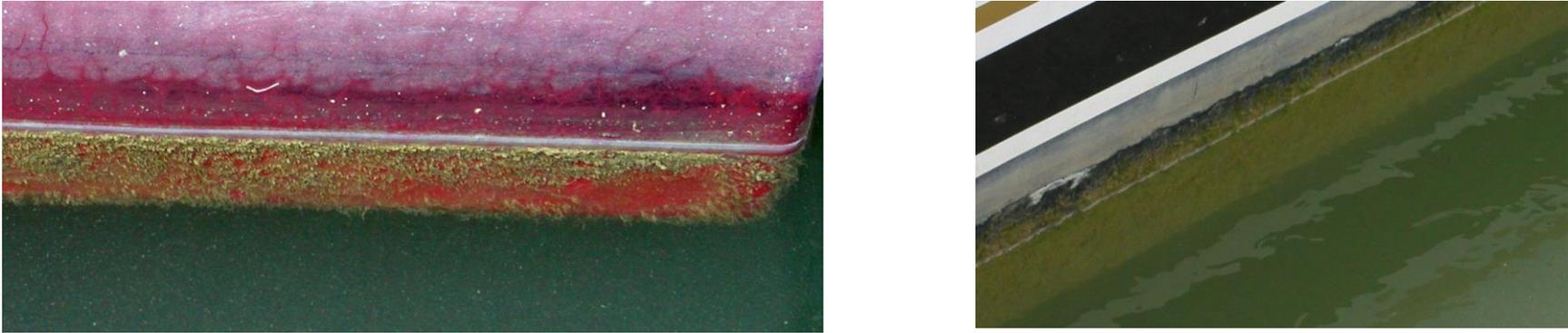
LoF rank	Criteria

2   Light fouling. 1 – 5 % of visible hull surface covered by macrofouling or filamentous algae. Usually remaining area covered in slime.

3   Considerable fouling. Macrofouling clearly visible but still patchy. 6 – 15 % of visible hull surface covered by macrofouling or filamentous algae. Usually remaining area covered in slime.

LoF rank	Criteria

4   Extensive fouling. 16 – 40 % of visible hull surface covered by macrofouling or filamentous algae. Usually remaining area covered in slime.

5   Very heavy fouling. 41 – 100 % of visible hull surface covered by macrofouling or filamentous algae. Usually remaining area covered in slime.

II. Allocation of LoF ranks by divers

Divers are able to see hull-fouling organisms in much more detail than a surface observer. Divers are also able to access the entire submerged part of a boat or ship. Especially in the case of large ships, fouling organisms are not uniformly distributed across the hull. Instead, their abundance greatly varies between the various 'niches' across a ship hull (Fig. 2), which should all be incorporated into a stratified sampling design:

(i)   bow,
(ii)   bow thruster,
(iii)   hull area below the waterline,
(iv)   waterline,
(v)   flat bottom keel,
(vi)   inside of the dry-docking support strips (DDSS), i.e. the areas on which the ship rests during dry-docking and which are not coated with antifouling paint,
(vii)   bilge keels (or wings),
(viii) sea chest gratings,
(ix)   stern,
(x)   propeller and its shaft, and
(xi)   rudder and rudder shaft
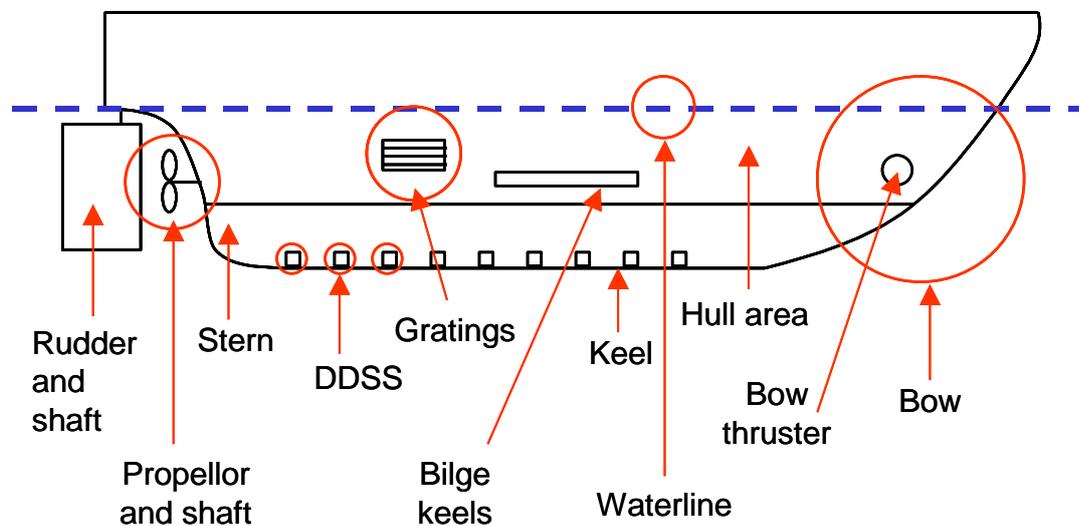
Fig. 2: Target areas on a vessel hull to estimate LoF by diving.

Divers should use the same criteria to determine LoF ranks as described above (Table 1) for surface based observations. Table 2 lists the LoF ranks and provides example images for each rank. A LoF rank should be provided *for each of the target areas identified above (i – xi and Fig. 2).*

Table 2: Criteria for allocation of LoF ranks by divers.

LoF rank	Criteria
0	No visible fouling. Hull entirely clean, no biofilm (slime) on any visible submerged parts of the hull.
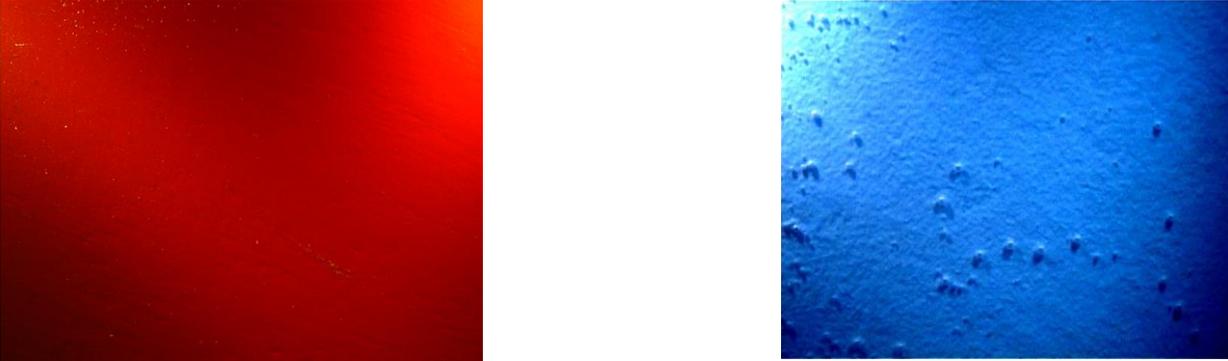
LoF rank	Criteria
1	Hull partially or completely covered in slime fouling (biofilm). Absence of any macrofouling.

LoF rank	Criteria
2	Light fouling. 1 – 5 % of visible surface covered by very patchy macrofouling or filamentous algae. Remaining area often covered in slime. Examples below show presence vs. absence of fouling in two adjacent areas of a hull (low LoF overall).
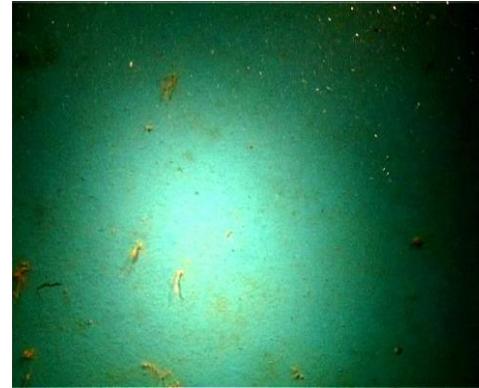
LoF rank	Criteria
3	Considerable fouling. Macrofouling clearly visible (usually > 1 species) but still patchy. 6 – 15 % of visible hull surface covered by macrofouling or filamentous algae. Remaining area often covered in slime.
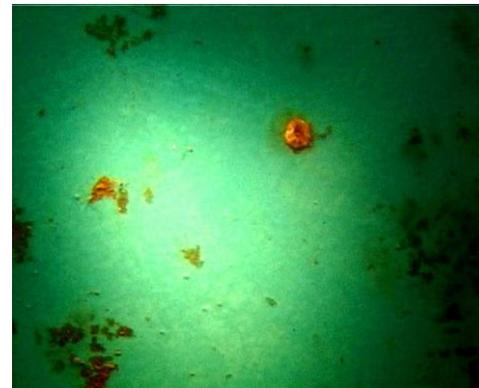
| LoF rank	Criteria
4	Extensive fouling. 16 – 40 % of visible hull surface covered by macrofouling or filamentous algae. Remaining area often covered in slime.

LoF rank	Criteria
5	Very heavy fouling. 41 – 100 % of visible hull surface covered by macrofouling or filamentous algae. Remaining area often covered in slime.

Levels of fouling (LoF) field sampling sheet

Vessel name: _____   **Port:** _____

Unique vessel sample code: _____   **Date:** _____

Sample/vessel no.: _____

Observer(s): _____

LoF ranks allocated   ☐ by surface observer   ☐ by divers

Ranking confirmed by team scientist: ☐ surface ranks   ☐ diving ranks

Surface image of vessel taken?   ☐ ID slate   ☐ stern   ☐ bow   ☐ hull midship

A. Rank allocation from the surface

Overall vessel: ☐ 0   ☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5
Bow: ☐ 0   ☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5
Waterline: ☐ 0   ☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5
Below waterline: ☐ 0   ☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5
Stern/rudder: ☐ 0   ☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Comments:

B. Rank allocation by divers

Diver-in-charge: _____

<div align="right">

LoF ranks

</div>

	N/a	Paint condition	0	1	2	3	4	5
Bow								
Bow thruster								
Hull below waterline								
Waterline								
Flat bottom keel								
DDSS								
Bilge keels								
Sea chest gratings								
Stern								
Propeller and shaft								
Rudder and shaft								

Comments: