



Assessing the Reliability of Self-Reports

Yvan Gauthier

Canada Command Operational Research & Analysis Team

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Background



- Vessels report themselves through various means:
 - Automatic Identification System (AIS)
 - Vessel Monitoring System (VMS)
 - Long Range Identification & Tracking (LRIT)
 - Weather reports
 - Pre-arrival notifications to authorities
 - etc.
- Self-reporting increasingly becoming mandatory (e.g., AIS now required for all ships ≥ 300 GT engaged on international voyages).
- A significant fraction of the data entering the recognized maritime picture is now coming from self-reports.



Issues



- Self-reporting systems are not tamper-proof. Vessels may report incorrect information, deliberately or not.
- Self-reports should be verified, to some extent, using other information sources.
- Various means of verification: aerial patrols, surface patrols, imagery, etc.
- Verifying all self-reports is impractical and not cost-effective.
- Key questions from the operators:
 - How many vessels should be verified?
 - Which ones?



How Many?



How many self-reporting vessels should be verified in order to reach a certain confidence level that the information received from all unverified vessels is correct?

- To answer this, some prior estimate of the fraction f of the vessel population that transmits incorrect information is required.
- Analysis performed on AIS reports (Gauthier, 2006). Estimated f for three types of “errors”:
 - insignificant (e.g., non-mandatory field missing);
 - minor (e.g., typo in ship name); and
 - serious (e.g., wrong ship location).



How Many?



- Let
$$(1 - f) = \text{probability that each vessel reports correct information;}$$
$$N_R = \text{number of self-reporting vessels; and}$$
$$N_V = \text{number of self-reporting vessels verified.}$$
- Assume independence between vessels and perfect error recognition.
- Also assume uniform sampling *without replacement* (each vessel is randomly selected and verified only once during a patrol).
- Probability P that all unverified vessels report correct information = $(1 - f)^{(N_R - N_V)}$

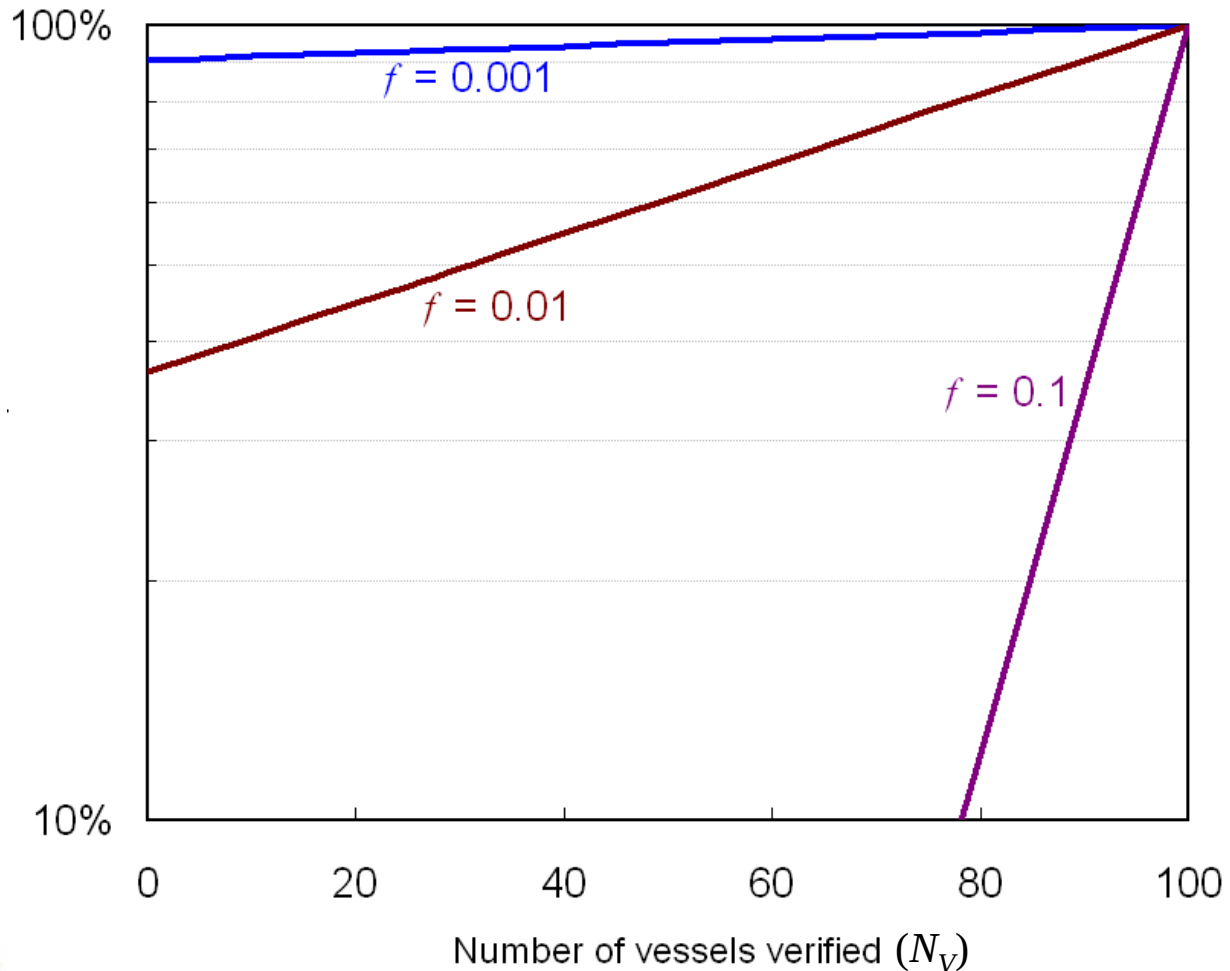
$$N_V = [\log(P) - N_R \log(1 - f)] / (1 - f)$$



How Many?



Example: Probability that *all* unverified vessels report correct information (with $N_R = 100$ vessels reporting)





How Many?



- Example of a simple spreadsheet-based estimation tool for operators.

The screenshot shows a spreadsheet application window titled 'Simulación 4.0 (English)'. The spreadsheet contains a table with the following data:

	A	B	C
1			
2		Requirement for the verification of self-reporting vessels	
3			
4		Average (historical) fraction of vessels NOT reporting correctly	0.004
5		Number of self-reporting vessels	97
6		Number of self-reporting vessels verified	65
7			
8		Probability that <i>all</i> unverified vessels report correctly	88.0%
9			
10			

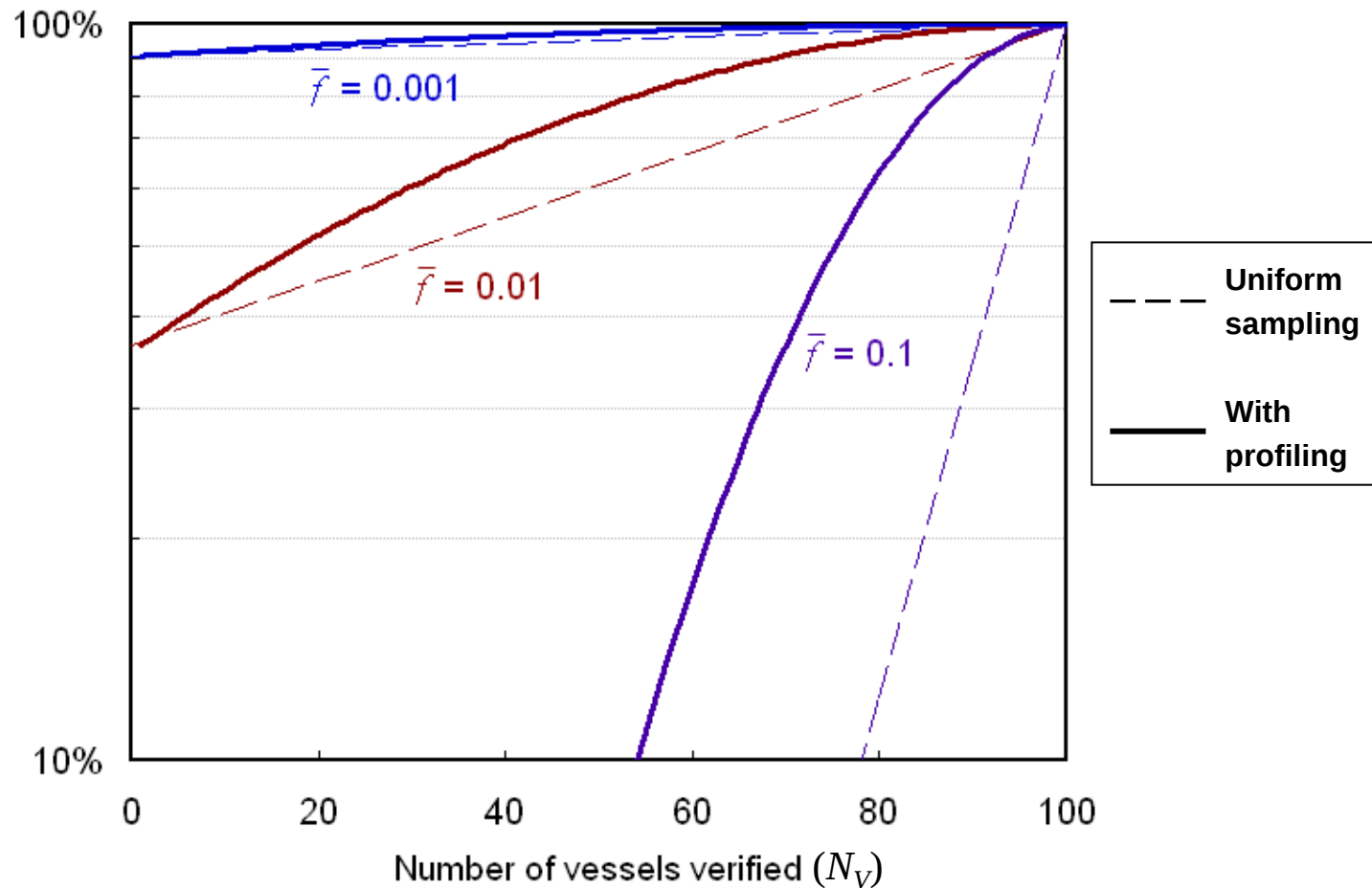


Which Ones?

- Uniform sampling is not the most efficient selection method.
- What if a meaningful probability f_i of reporting incorrect information can be assigned to each vessel $i = 1, \dots, N_R$?
- Optimal verification strategy:
 - Sort f_i 's from largest to smallest value.
 - Focus available time and resources on vessels with the highest f_i 's.



Example: Probability that *all* unverified vessels report correct information (with $N_R = 100$ vessels and $f_i = i \cdot f / 2$)





Which Ones?

Case with replacement



- Consider now a very large area monitored over a very long period (e.g. 1 year)
- A vessel may then be verified multiple times by multiple patrols, patrol assets, or agencies. This is sampling *with replacement*.
- Does the optimal verification strategy remains the same?



Which Ones?

Case with replacement



- No!
- “Strong profiling is not mathematically optimal for discovering rare malfeasors” (W.H. Press, *Proceedings of the National Academy of Sciences*, Feb 2009)
- When sampling proportionally to the f_i 's (strong profiling), resources are wasted on the repeated verification of vessels that are correctly reporting.
- Priors should be used, *but only weakly*.



Which Ones?

Case with replacement



- Optimal verification strategy:
 - Estimate f_i for every vessel.
 - Perform *square-root biased* sampling (proportional to $\sqrt{f_i}$) on the vessel population.
- Example:
 - If a vessel is *a priori* 25 times more likely than average to report incorrect information, it should be verified only 5 times more frequently than average.
- Theoretically valid for any type of vessel profiling, although not all profiling methods may be legal or feasible.



Operational Considerations

- Self-report verification is generally not the primary objective of surveillance activities.
- Even if verification is performed as a secondary task, operators should:
 - record number of verifications and details of incorrect reports;
 - record reporting vessel characteristics; and
 - refine priors as more data becomes available.
- In practice, sampling involves tradeoffs between verification effort (time, distance) and the number of vessels verified.
- If priors can be assigned to different categories of vessels, sampling should be kept roughly proportional to $\sqrt{f_i}$.



Conclusion

- Simple statistical methods can be easily implemented by authorities to assess the reliability of self-reports.
- More sophisticated Bayesian procedures could also be investigated (e.g., procedures based on anomaly detection).
- Good estimates of the priors are key to reliability assessments. Verification results should be compiled and analyzed on a regular basis to refine priors.
- Enforcing regulations more stringently would increase self-report reliability in the medium term. Verification data could be used to measure the impact and cost-effectiveness of this enforcement.



Comments? Questions?

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