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**Postscript on ATA trawl experiment**

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Postscript on ATA Trawl Experiment

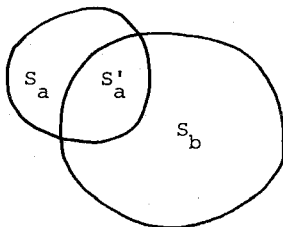
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This is a discussion on bias of estimators arisen from imperfect performance, in terms of areal coverage, of the ATA trawl experiment that are categorized by the following three types:

- (1) Follow-towing of A and B trawlers made insufficient coverage of trawl area (A-B attacker bias)
- (2) Only follow-towing of A made such insufficient operation but performed perfectly by follow-towing of B (A attacker bias)
- (3) In reverse the above, A was right but B was insufficient for respective follow-towing operation (B attacker bias)

Schematic figure can draw as follows:



VULNERABILITY ESTIMATION

- (1) Certain unoverlap of trawl area were made by both A and B attackers

Formulas (2) and (3) should be changed as follows, where  $S'_a/S_a = p$

and  $p = \text{constant}$ ,

$$Y_{1b} = b[d_1(S_b - S'_a) + (d_1 - \frac{Y_{1a}}{S_a})S'_a]$$

$$= b(d_1 S_b - pY_{1a}) \quad \dots\dots\dots(9)$$

$$\begin{aligned}
Y_{2a} &= a[(d_2 - \frac{Y_{2b}}{S_b})S'_a + d_2(S_a - S'_a)] \\
&= a(d_2 - \frac{Y_{2b}}{S_b})S_a \quad \dots\dots\dots(10)
\end{aligned}$$

Solutions of a and b, therefore, are as follows:

$$a' = s(y_2 - y_1)py_2(y_1 + 1) \quad \dots\dots\dots(11)$$

$$b' = (y_2 - y_1)/p(y_2 + 1) \quad \dots\dots\dots(12)$$

(2) Unoverlap of trawl area was made by a attacker, but not by B

Using the formulas (1), (2), (4), and (10),

$$a'' = s(y_2 - y_1)/y_2(py_1 + 1) \quad \dots\dots\dots(13)$$

$$b'' = (y_2 - y_1)/(py_2 + 1) \quad \dots\dots\dots(14)$$

(3) Unoverlap of trawl area was made by B attacker, but not by A

Using the formulas (1), (3), (4), and (9),

$$a''' = s(y_2 - y_1)/y_2(y_1 + p) \quad \dots\dots\dots(15)$$

$$b''' = (y_2 - y_1)/(y_2 + p) \quad \dots\dots\dots(16)$$

BIAS OF VULNERABILITY ESTIMATOR

Relative error caused by irregular ATA trawl can formulate as follows:

For A-B attacker bias

$$a'/a = 1/p, \quad b'/b = 1/p \quad \dots\dots\dots(17)$$

For A attacker bias

$$\left. \begin{aligned}
a''/a &= (y_1 + 1)/(py_1 + 1), \\
b''/b &= (y_2 + 1)/(py_2 + 1)
\end{aligned} \right\} \quad \dots\dots\dots(18)$$

For B attacker bias

$$\left. \begin{aligned} a''' / a &= (y_1 + 1) / (y_1 + p), \\ b''' / b &= (y_2 + 1) / (y_2 + p) \end{aligned} \right\} \dots\dots\dots(19)$$

#### CONCLUSION

When ATA trawl experiment was performed imperfectly in terms of areal coverage, that perfect ATA operation of follow-towing gear should or should be include completely swept-area made by the lead-towing gear, a possible bias of estimator is summarized as follows:

- (1) Estimators are commonly overestimating the vulnerability, if unoverlap area for each ATA subset was introduced in the experiment.
- (2) Bias made by both A and B attackers is proportional reversely to relative overlapping area against the whole swept-area of A which is small gear.
- (3) B attacker bias is relatively small than A attacker bias, if  $p$  and  $y_1$  (or  $y_2$ ) belonging to A attacker are same to that of B attacker.
- (4) Isobias contour lines made by incomplete follow-towing of B have a character that the bias decreases by increasing  $y_1$  (or  $y_2$ ).
- (5) So far as big value of  $y_1$  (or  $y_2$ ) is concerned, isobias contour line made by incomplete follow-towing of A are rather flat shape, in other words, A attacker bias is analogous to A-B attacker bias in right hand side of  $y$ .

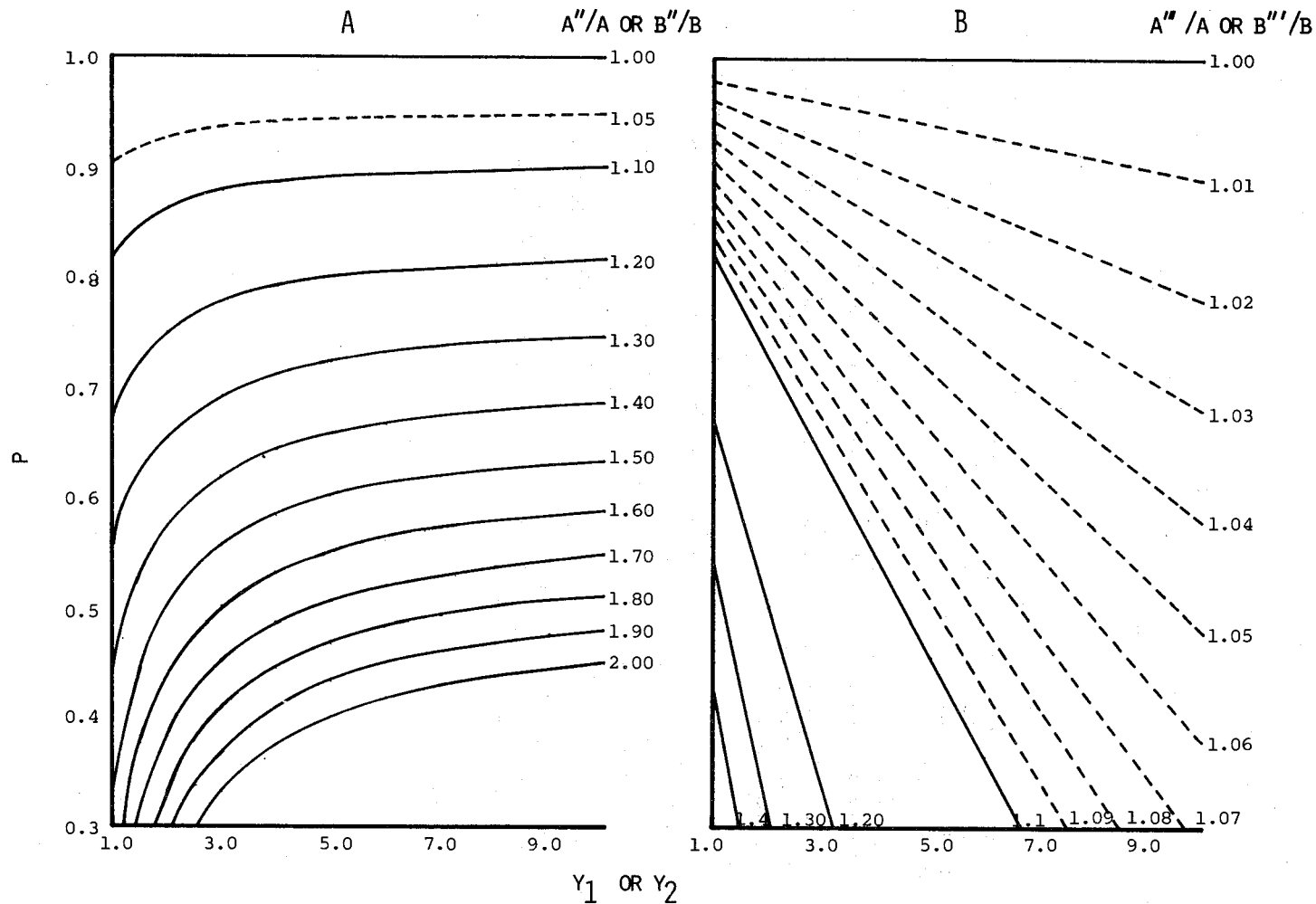


Fig. 1 Isobias contour on vulnerability generated from irregular ATA trawl operation.

A ... A attacker bias, formula (18), B ... B attacker bias, formula (19)