## Local Sensitivity Analysis for the FishCensus Model

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For more information, model code and documentation, visit https://www.openabm.org/model/5305/.

In order to understand how sensitive the output of the model is to small changes in parameters, a local sensitivity analysis was run using 30x2 m transects, a diver swimming at 8 m per minute with a visibility of 6 metres and true density of fish fixed at 0.2 fish per $m^2$. 15 replicates were run for each parameter.

For the purpose of this analysis, five fish types were created (tables 1 and 2): A basic type without schooling behaviour or urge to rest and detectability set to 1, a variation of this type with schooling behaviour to test changes in schooling parameters, a second variation with 50% detectability to test changes in this parameter and a third variation with a rest urge of 5 to test changes in the magnitude of this vector. The fifth type is a complex schooling species with three behaviours, used to test behaviour change interval and frequencies (table 2).

Behaviour change interval (10 seconds) and count saturation (3 fish per second) are two structural parameters of the model (even though they can be changed in the interface), which had to be somewhat arbitrarily set.

The “Complex” fish type was used to test the sensitivity to behaviour change interval (tables 1 and 2). Increasing behaviour change interval by 1 second (10%) led to an average increase of 15.2% (8.3% SE) on the estimated density, while decreasing this parameter by 1 second led to an increase of 4.1% (7.2% SE). These values suggest the output is relatively robust to small changes in this model simplification parameter. For the count saturation, counting 1 less fish per minute led to an increase in 0.4% in the output (3.8% SE) and counting one more fish led to a 1.6% increase (4.0% SE).

Table 1. Fixed attributes for the five generic fish types used as controls for sensitivity analysis. The four basic fish types have similar fixed attributes and differ only on the behaviour parameters (table 2).

| | Basic (4 types) | Complex (1 type) |
|---|---|---|
| Size (m) | 0.3 | 0.2 |
| ID distance (m) | 5 | 4 |
| Approach distance (m) | 1.0 | 1.0 |
| Perception distance (m) | – | 0.35 |
| Perception angle (degrees) | 320 | 320 |
| Max. acceleration ($m/s^2$) | 0.15 | 0.2 |
| Max. sustained speed (m/s) | 0.5 | 0.5 |
| Burst speed (m/s) | 2.9 | 2.6 |

The sensitivity of fish attributes and behaviour submodel parameters will likely be influenced by the combination of behaviours, frequencies, sampling method, visibility, among other factors, in a way that would be overwhelming and too computationally intensive to approach exhaustively. Instead, users of FishCensus are encouraged to look at sensitivity for their particular species and method of interest. The generic species used in this simple sensitivity analysis have a single behaviour with most urge vectors set to an intermediate value (5), so changing this value by an integer corresponds to a 20% variation of the input (figure 1).

Table 2. Behaviour parameters for the five generic fish types used as controls for sensitivity analysis. The first four types are variations of the basic type, all with a single behaviour and with changes highlighted in bold. The fifth is a complex schooling species with three behaviours.

| | Fish type name | Basic | School | Detectability | Rest | Complex | | |
|---|---|---|---|---|---|---|---|---|
| | Behaviour name | basic | basic | basic | basic | wandering | feeding | stationary |
| | Frequency | 1 | 1 | 1 | 1 | 0.5 | 0.2 | 0.3 |
| | Detectability | 1 | 1 | **0.5** | 1 | 1 | 1 | 1 |
| | Schooling? | FALSE | **TRUE** | FALSE | FALSE | TRUE | TRUE | TRUE |
| | Schoolmate distance (BL) | – | 1 | – | – | 1 | 1 | 1 |
| | Patch distance (m) | – | – | – | – | – | 1 | – |
| Urge weights | Align | – | **5** | – | – | 5 | 1 | 5 |
| | Centre | – | **5** | – | – | 6 | 2 | 6 |
| | Spacing | – | **5** | – | – | 15 | 5 | 15 |
| | Wander | 5 | 5 | 5 | 5 | 3 | 1 | 1 |
| | Rest | 0 | 0 | 0 | **5** | 0 | 1 | 7 |
| | Cruise | 5 | 5 | 5 | 5 | 0 | 0 | 0 |
| | Patch gathering | – | – | – | – | – | 10 | – |
| | Diver avoidance | 5 | 5 | 5 | 5 | 10 | 10 | 10 |

The sensitivity of behaviour frequency was assessed by shifting the frequency of the "wander" behaviour of the complex fish by 0.1 in both directions, and diluting this change on the other two behaviours (table 2).

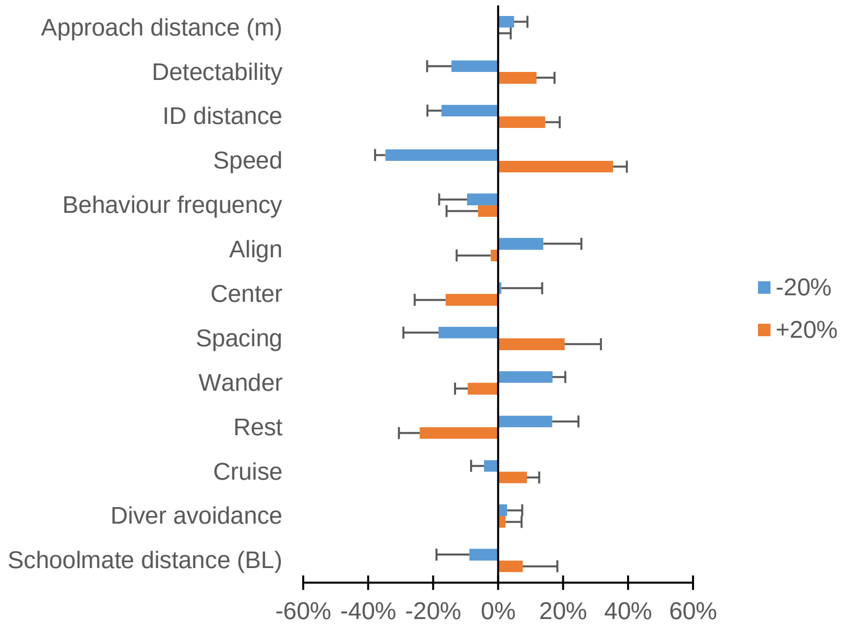


Figure 1. Percent change in output (fish density estimated by the diver) with an increase or decrease in 20% of the input parameters relative to control. Values calculated from 15 replicates using 30x2 m transects, with a swim speed of 8 metres per minute and a visibility of 6 metres. True density was fixed at 0.2 fish per square metre.

For the speed attribute, the cruise speed was shifted 20% in both directions and the burst speed was also adjusted by the same amount (not the same percentage). Even though this is a simple approach that disregards all possible interactions among parameters, it is evident from figure 2 that the model is particularly sensitive to fish movement speed (maximum speed and the magnitude of the rest urge). The rest urge adds additional drag to fish movement, regardless of their maximum speed, so changing this urge can drastically change the average speed and thus impact the visual counts. Maximum speed, however, is one of the most important attributes in the model, requiring a particularly informed parameterisation, either from laboratory measurements, video analysis or by using a proxy such as the caudal fin aspect ratio approach implemented in the model interface.

For schooling behaviour, the output seems to be particularly sensitive to the spacing between schoolmates. Decreasing or increasing the distance by 20% led to a decrease or increase in output by about 20%, respectively. Because increasing the "centre" urge vector leads to more compact schools, it is analogous to decreasing the distance in terms of sensitivity.

The effect of changing fish view angle was also tested, but as in this case it is impossible to increase it by 20%, this parameter was tested by reducing or increasing the angle in 10 degrees (3%). In this case a decrease led to a 2.0% average increase in estimated density (4.0% SE), while an increase led to an average increase of the output in 1.8% (3.9% SE). Because this was done on the “basic” fish type (tables 1 and 2), view angle only affects the reaction of fish to the diver. Changing the view angle on a schooling fish tends to affect the shape and size of schools, and therefore model sensitivity is probably affected differently.