

## EXERCISE 3: Build up models for marine disease transmission through filtration of environmental pathogens pathogens

**Learning objective:** The learning goal of this lesson is to construct disease models describing pathogen transmission through filtration of environmental pathogens.

The learner will try to construct the SIPF (Susceptibles-Infected-Pathogens-Filtration) and SIPDF (Susceptibles-Infected-Pathogens-Dead-Filtration) models with Matlab using differential equations. For this, the learner will build up the model using the SIP and SIPD model codes from previous Exercise 1. The student will need to add a new variable  $F$  and two new parameters (filtration rate, in vivo decay rate, particles removal rate from the environment) to incorporate the filtration process of susceptibles removing infectious particles from the water column. The student will need to spend 15 hours to (1) set the equations, (2) code those in Matlab, (3) run a set of simulations with different parameter values and initial conditions, (4) and verify that the model behavior is suitable analyzing outputs (plots).

### The exercise

The student will try to build up two models to describe marine disease transmission through filtration of environmental pathogens. These two models can be built up using SIP and SIPD models as base models. For this, the student needs to know that some marine microparasitic pathogens can survive several months in the water column to be

absorbed by filter-feeders (e.g. bivalves).

In these models, the student will assume that the host can also fight against the pathogen (e.g. phagocytosis). The models will consider the transmission from the environment occurring via pathogens released from infected and dead infected animals at a given rate  $c$  as in SIP and SIPD models. In this SIPF model, pathogens are released by infected animals.

The models to construct by the student will be named SIPF and SIPDF models. In the SIPF model, the variables are Susceptible animals  $S$ , Infected animals  $I$  and environmental or free-living pathogens (infectious particles)  $P$ , and internal pool of infectious particles inside the susceptible population  $F$ . In this model, pathogens are released by  $I$  and filtered out by the  $S$  and  $I$ .

Considering that  $f$  is the portion of the local volume filtered per individual and time, the number of pathogens removed from the local volume ( $1 m^3$ ) by a susceptible individual per time will be  $fP$  and the number of pathogens filtered by the population from the local volume will be represented by  $fPS$ . Pathogens in the environment can be lost using an environmental decay rate of pathogens  $r$  as in model SIP.

The model should incorporate a rate, for example  $a$ , to estimate the inactivation of pathogens by the animal or pathogens lost from the animal.  $F/S$  can represent the average pathogen body burden of the susceptibles. Consequently, disease transmission should be linearly proportional to the average body burden per individual times the number of individuals; that is,  $\beta_{filtration}(F/S)S$ .

This model diverges from previous models in three important ways: (1)  $S$  no longer is present as a discrete variable in equations: the variable  $F$  acts as a surrogate; (2)

infective particles are lost due to mortality or dilution  $r$ , but also by filtration  $f$ : that is, the population is an active contributor to particle loss; and (3) the dose-response relationship can be described by the new equation for  $F$  relating filtration  $f$  to particle inactivation/loss  $a$ .

The second model, SIPFD model, incorporates dead infected animals  $D$ . In this model pathogens are released by  $D$  instead of by  $I$  and filtered out by  $S$  and  $I$ . In addition to parameters  $c$ ,  $f$ ,  $a$  and  $r$ , this model needs to consider the parameter describing the decay rate of dead infected animals.

Similarly to models described in lesson 4 and previous exercise, the student will try to build the ODEs and the MATLAB scripts (4 scripts) correspondent to each model. Some model diagnostics (plots) as in lesson 4 or new ones are necessary to complete the exercise.