ECASA - Model description

1	**Name of model**	*Reporter/Institute (email address)*
1.a	***KK3D***	Marko Jusup Rudjer Boskovic Institute (RBI). Institut Ruder Boškovic, Bijenicka cesta .54, POB 180, HR-10 002 Zagreb, Hrvatska, Croatia. email: marko.jusup@irb.hr Tel. + 385-1-4680230
1.b	*date this form was completed or updated*	19 July 2007

2	**Short DESCRIPTION of model**	
2.a	*Main state variables:*	Benthic Carbon Loading (BCL in $gC/m^2/day$)
2.b	*Scale to which applicable:*	A KK3D predicts deposition of organic waste beneath a fish farm. At a typical farming site water column depth is below 80 m. Particles which emanate from the farm sink at average velocity equal or greater than 0.5 cm/s and currents in the Adriatic are always below 0.5 m/s. In such conditions, particles cannot disperse more than 8 km away from the farm. In practice, however, impacts of farming on the sediment do not extend more than 300 m away from the net pens. Thus KK3D model operates on a very local scale.
2.c	*General description.*	KK3D is a Random Displacement Model (RDM) which belongs to a broad class of Lagrangian Stochastic Models (LSM). It is based on stochastic differential equations which are equivalent to the well-known semi-empirical advection-diffusion equation. The model is thoroughly described in Jusup et al. (2007). Wilson (2000) classifies RDM as a "zeroth-order" LSM noting its main weakness; if xi(t) is treated as Markovian random variable, the model cannot be valid close to the source, that is for travel times shorter than the velocity correlation timescale. The more advanced, "first-order" LSM, called Langevin Equation Models (LEM), have been used extensively in atmospheric research owing much of their popularity to analytical description of turbulence properties in the surface boundary layer. This turns out to be an impossible task in oceanographic application (Brickman and Smith, 2002) where turbulent quantities are provided by circulation models with incorporated appropriate closure scheme (e.g. Warner et al., 2005). Furthermore, there is a problem of so-called trajectory crossing. Initially the heavy particle position will coincide with the position of some fluid element. As the time passes, particle drifts away from the fluid element because of its settling rate, leaving the eddy in which correlation with initial velocity still exists. Therefore, it is suggested to reduce the heavy particle correlation

		timescale with respect to the fluid element timescale (e.g. Wilson, 2000), but this is a heuristic approach. There is also a possibility that due to finite inertia, heavy particle is unable to follow rapid velocity fluctuations, resulting in a different velocity variance compared to the fluid element. Our objective was to construct a model that is usable in many different locations prior to installation of an aquaculture facility. In such situations, at best, measured current profiles are available as input data. So to avoid unnecessary complexities and account for dispersion, one must impose reasonable assumptions about joint moments of concentration and velocity fluctuations. The simplest and widely used example is the eddy diffusion hypothesis.
2.d	*Key semi-universal parameters and example values (which should apply at least regionally or for at least one type of water body); summarize any restrictions or reservations about these parameters*	Horizontal eddy diffusion coefficients are set to 0.1 m^2/s. Vertical eddy diffusion coefficient is 0.001 m^2/s. Although these values are based on measurements (Cromey et al., 2002) they should change with settling velocity of particles (feed or faeces, see General description). Also, turbulent properties (kinetic energy, dissipation) changes through the water column and some vertical structure should be ascribed to diffusion coefficients.
2.e	*Main forcing data needed - initial values of state variables; boundary conditions; inputs; imposed environmental conditions; generalized loss terms. State whether single values or time-series needed.*	The measurements needed for calibrating the model to the local conditions are: - Current data (at least 15 days) - Bathymetry - Fish farm layout - Emission of particulate organic matter from the farm
2.f	*Restrictions to use of model*	The model requires calibration with field data.

3	**possibly relevant INDICATORS**	
3.a	***D**river*	Aquaculture facility
3.b	***P**ressure*	Emission of particulate organic matter from the farm
3.c	***S**tate*	Benthic Carbon Loading, dissolved oxygen
3.d	***I**mpact*	Hypoxia and anoxia, H_2S degassing from the sediment
3.e	***R**esponse*	Exchange of benthic communities beneath the farm

4	**STATUS of model** *NB: refers to scientific theory and equation set; distinguish from implementation*	
4.a	*Origin(ator) of model concept and initial formulation:*	The first version of KK3D was developed by Sunčana Geček at the Laboratory of Ecological Modelling (RBI) within the project Ecological Models of Aquatic Ecosystems financed by the Ministry of Science, Education and Sports in Croatia.
4.b	*Present status of model, including scientific basis of*	Presently KK3D consists of two modules: particle tracking and oxygen consumption module (similar to the module

	claimed robustness and key matters still needing study:	described by Stigebrandt et al., 2004). Particle tracking was validated by the sediment trap validation study within the ECASA project.
4.c	*Present use:*	KK3D has been used in several Environmental Impact Assessment Studies for mariculture in the Adriatic Sea.
4.d	*Potential use and development in ECASA :*	Model can be used at any mariculture site in ECASA. Major development would be insertion of new modules (e.g. resuspension module) and model validation.

5	**IMPLEMENTATION of model**	
5.a	*State of implementation :* *(This refers to realization of model theory in numerical algorithms, spreadsheets, computer programs, etc. to provide solutions of the model equations when supplied with appropriate forcing data.*	Algorithms programmed in C++. Presently running under GNU/Linux.
5.b	*State of documentation (which describes how to use an implementation as well as giving model theory)*	No real manual is available at present.
5.c	*Intellectual property concerns - if none stated here, model and implementation will be deemed to freely available on request*	Model algorithms, source and executable code for implementation are property of RBI.

6.	**TESTING of model**	
6.a	*Summary of conditions and measurements needed:* *Refer back to 2.e if necessary. Highlight observations needed for model testing.*	The measurements needed for calibrating the model to the local conditions are: - Current data (at least 15 days) - Bathymetry - Fish farm layout - Emission of particulate organic matter from the farm
6.b	*Criteria for model rejection*	-

7	**OTHER models**	
7.a	*Used explicitly or implicitly with this model*	-
7.b	*Similar models (which might serve roughly the same purpose in relation to mariculture)*	DEPOMOD TRIMODENA-LPT MOM

8.	**REFERENCES cited**	*show in bold the most important paper describing the model*

Brickman, D., Smith, P.C., 2002. Lagrangian stochastic modelling in coastal oceanography. J. Atmos. Ocean. Tech. 19, 83–99.

Cromey, C.J., Nickell, T.D., Black, K.D., 2002. DEPOMOD-modelling the deposition and biological effects of waste solids from marine cage farms. Aquaculture 214, 211–239.

Jusup, M., Geček, S., Legović, T., 2007. Impact of aquacultures on the marine ecosystem: Modelling Benthic Carbon Loading over variable depth. Ecological modelling 200, 459-466

Stigebrandt, A., Aure, J., Ervik, A., Hansen, P.K., 2004. Regulating the local environmental impact of intensive marine fish farming. III. A model for estimation of the holding capacity in the Modelling-Ongrowing Fish Farm-Monitoring System. Aquaculture 234, pp. 289–261.

Warner, J.C., Sherwood, C.R., Arango, H.G., Signell, R.P., 2005. Performance of four turbulence closure models implemented using a generic length scale method. Ocean Model. 8, 81–113.

Wilson, J.D., 2000. Trajectory models for heavy particles in atmospheric turbulence: comparison with observations. J. Appl. Meteorol. 39, 1894–1912.