The following supplement accompanies the article

Intra-individual behavioral variability displayed by tuna at fish aggregating devices (FADs)

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Supplementary Material. Supplementary material includes detailed information on the equations fitted, statistical procedures used to investigate behavioral variability, and detailed results of model fitting and comparison

METHODS

Model fitting

The survival curve mathematical framework examines and models the time it takes for events to occur. The events are assumed to be generated by a Poisson process, which results in the time between events being exponentially distributed. The exponential distribution commonly used to model waiting times between 2 events has a "memoryless" characteristic. The probability that an event occurs within an additional length of time t is independent of the time elapsed to this point.

$$S(t) = f_1 \cdot \exp(-k_1 \cdot t) \qquad (1)$$

In Eq. (1), $S(t)$ represents the proportion of survival times in the sample greater than t, f_1 the fraction of the observed survival times characterized by the equation; k_1 the exponential parameter is interpreted as the probability for events to occur at each time step and t the time.

$$S(t) = f_1 \cdot \exp(-k_1 \cdot t) + (1-f_1) \cdot \exp(-k_2 \cdot t) \qquad (2)$$

Eq. (2) is a sum of 2 exponentials where f_1 is the fraction of the survival times which belongs to the population 1 and $1 - f_1$ the fraction of the observed survival times which belongs to the population 2. Parameters k_1 and k_2 are the probabilities that an event occurs for sub population 1 and 2, respectively. As in Eq. (1), $S(t)$ is the proportion of survival times in the sample greater than t and t the time

$$S(t) = \theta / (\beta + t)^{\alpha} \text{ where } \theta = \beta^{\alpha} \qquad (3)$$

Eq. (3) is a general power law which tends to a power law decay at long time where α is the power coefficient. β corresponds to the minimal value of t. In this model, the probability that the event occurs is time dependent and decreases with the residency time.

Parameters (f_1, k_1, k_2; θ, β, α) were estimated using nls procedure in R.

Behavioral variability

We used an ANOVA (chi-square statistic) to compare 2 nested models. Model 0 (a generalized linear model (glm) with a binomial error distribution) corresponds to the null hypothesis that the probability of occurrence of the short associative behaviour is the same among fish. Model 1 (glm binomial) corresponding to the alternative hypothesis in which at least one fish has a probability which differs from the others.

RESULTS

Continuous residence time (CRT)

First family of statistical units (SUs) : FADs HH-2003-March-June and LL-2004-February-March

Table S1. Model comparison (Akaike information criterion, AIC) and estimated parameters of the 3 models tested on the family of SUs including CRTs displayed at FADs HH-2003-March-June and at LL-2004-February-March

Model	Parameter	Estimate	Pr(>|t|)	AIC
Single exponential				
	f_1	0.96	$<2 \times 10^{-16}$	–152.19
	k_1	0.043	$<2 \times 10^{-16}$	
Multiple exponential				
	f_1	0.05	6.98×10^{-5}	–155.12
	k_1	2.345	0.32	
	k_2	0.042	$< 2 \times 10^{-16}$	
Power low				
	α	12.83	0.27	–137.48
	β	269.45	0.29	

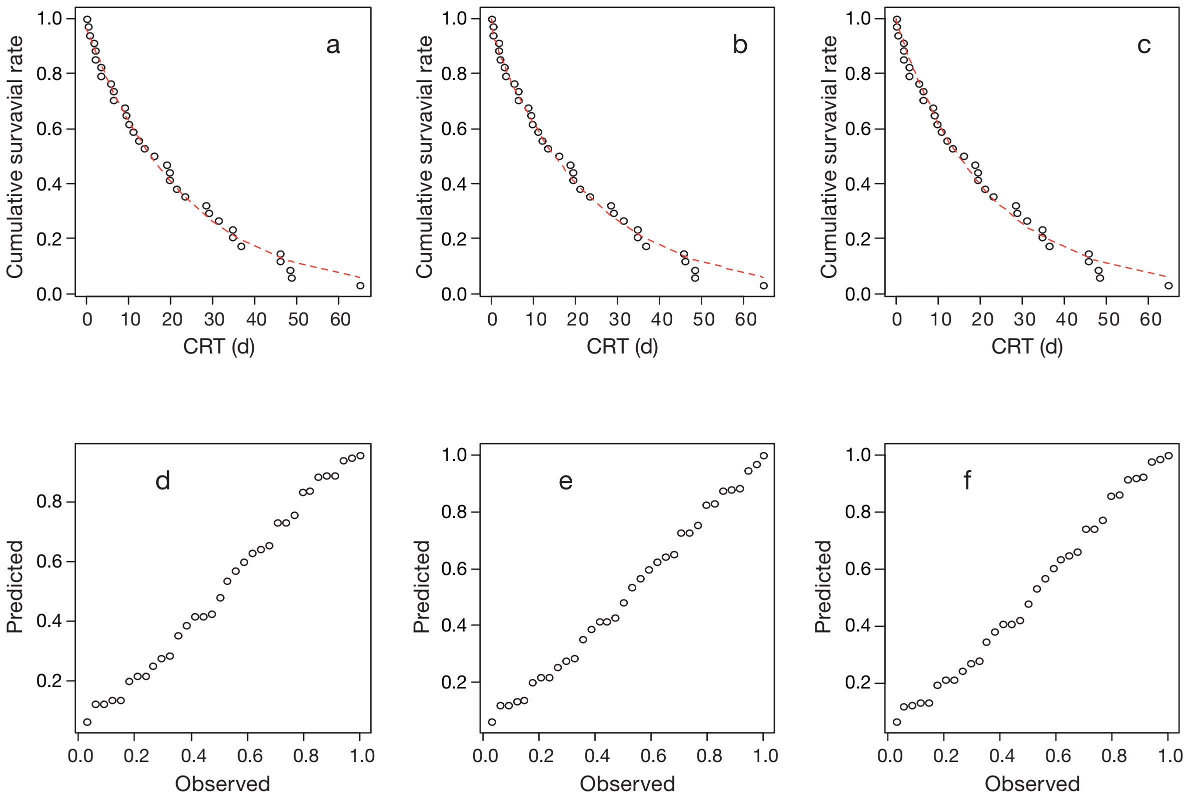

Fig. S1. Goodness of fit of the 3 models tuned on the family of statistical units (SUs) including continuous residence times (CRTs) displayed at FADs HH-2003-March-June and at LL-2004-February-March. In panels (a,b,c) dots represent observed CRTs and dashed red line the model fitted. Panels (d,e,f) represent the quantile quantile plot for each model tested. Panels (a,d) described the single exponential model, panels (b,e) the multiple exponential model and panels (c,f) the power low model

Second family of statistical units (SUs): FAD R-2002-October-November

Table S2. Model comparison (Akaike information criterion, AIC) and estimated parameters of the 3 models tested on the family of SUs including continuous residence times (CRTs) displayed at FAD R-2002-October-November

Model	Parameter	Estimate	Pr(>|t|)	AIC
Single exponential				
	f_1	0.96	1.37×10^{-9}	–20.01
	k_1	0.072	4.15×10^{-6}	
Multiple exponential				
	f_1	5.99×10^{-2}	0.39	–18.34
	k_1	3.43×10^{1}	0.97	
	k_2	7.09×10^{-2}	2.79×10^{-5}	
Power low				
	α	15.82	0.913	–19.10
	β	200.00	0.916	

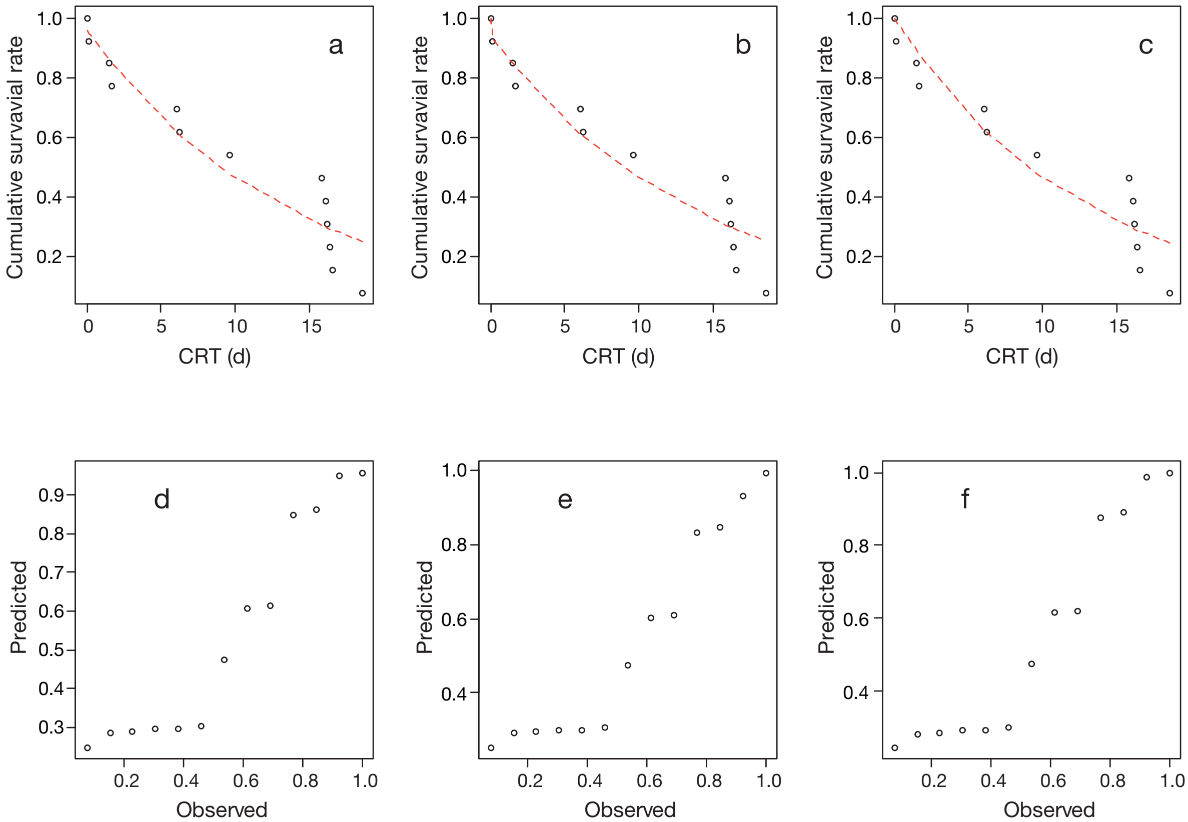

Fig. S2. Goodness of fit of the 3 models tuned on the family of statistical units (SUs) including continuous residence times (CRTs) displayed at FAD R-2002-October-November. In panels (a,b,c) dots represent observed CRTs and dashed red line the model fitted. Panels (d,e,f) represent the quantile quantile plot for each model tested. Panels (a,d) described the single exponential model, panels (b,e) the multiple exponential model and panels (c,f) the power low model

Third family of statistical units (SUs): FADs V-2003-March-May, CO-2003-February-March, R-2005-January-April and S-2005-January-April

Table S3. Model comparison (Akaike information criterion, AIC) and estimated parameters of the 3 models tested on the family of CRTs (SUs) including continuous residence times (CRTs) displayed at FADs V-2003-March-May, CO-2003-February-March, R-2005-January-April and S-2005-January-April

Model	Parameter	Estimate	Pr(>|t|)	AIC
Single exponential				
	f_1	0.79	$<2 \times 10^{-16}$	–179.54
	k_1	0.559	$<2 \times 10^{-16}$	
Multiple exponential				
	f_1	3.64×10^{-1}	$<2 \times 10^{-16}$	–343.70
	k_1	1.10×10^{2}	$<2 \times 10^{-16}$	
	k_2	3.42×10^{-1}	$<2 \times 10^{-16}$	
Power low				
	α	0.26	$<2 \times 10^{-16}$	–211.12
	β	0.016	3.28×10^{-5}	

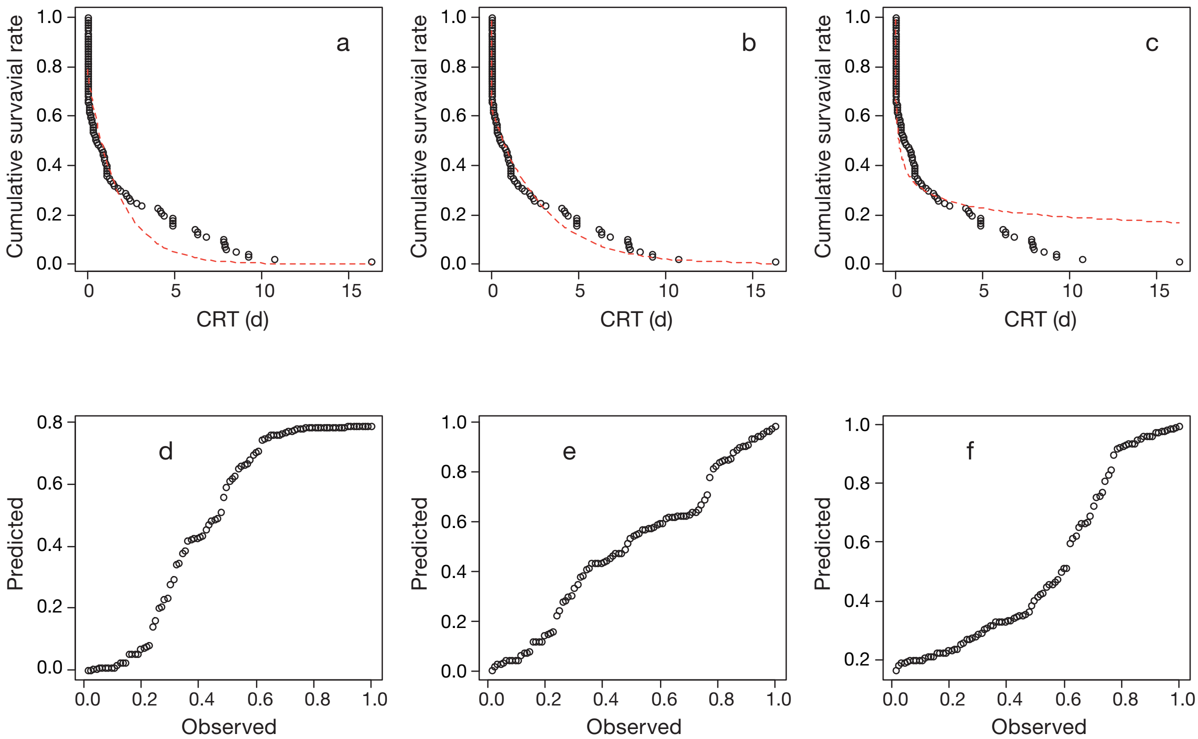

Fig. S3. Goodness of fit of the 3 models tuned on the family of statistical units (SUs) including continuous residence times (CRTs) displayed at FADs V-2003-March-May, CO-2003-February-March, R-2005-January-April and S-2005-January-April. In panels (a,b,c) dots represent observed CRTs and dashed red line the model fitted. Panels (d,e,f) represent the quantile quantile plot for each model tested. Panels (a,d) described the single exponential model, panels (b,e) the multiple exponential model and panels (c,f) the power low model

Continuous absence time (CAT)

Table S4. Model comparison Akaike information criterion (AIC) and estimated parameters of the 3 models tested on the family of statistical units (SUs) including CATs displayed between March and July 2003 and between January and April 2005

Model	Parameter	Estimate	$Pr(>\|t\|)$	AIC
Single exponential				
	f_1	1.05	$<2 \times 10^{-16}$	–415.50
	k_1	0.352	$<2 \times 10^{-16}$	
Multiple exponential				
	f_1	0.93	$<2 \times 10^{-16}$	–416.55
	k_1	0.362	$<2 \times 10^{-16}$	
	k_2	0.017	0.42	
Power low				
	α	7.91	0.02	–394.93
	β	23.23	0.03	

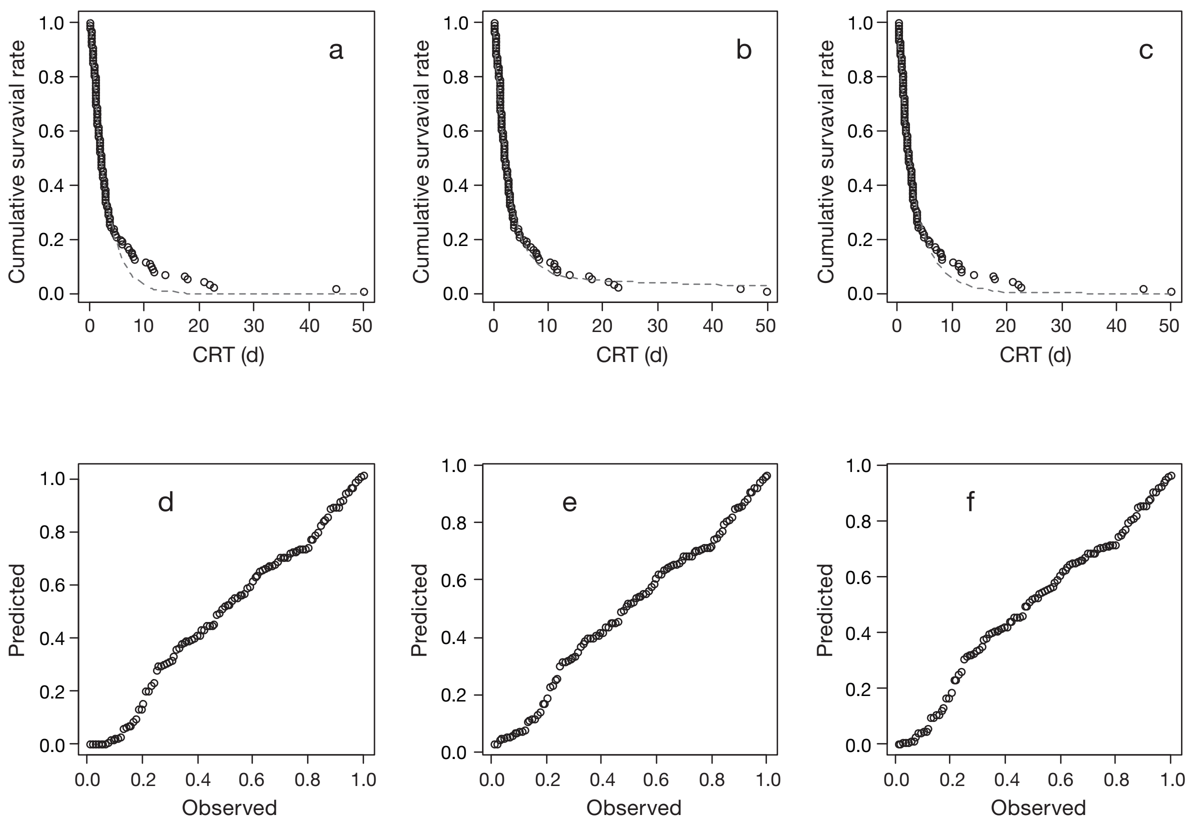

Fig. S4. Goodness of fit of the 3 models tuned on the family of statistical units (SUs) including continuous absence times (CATs) displayed between March and July 2003 and between January and April 2005. In panels (a,b,c) dots represent observed CATs and dashed red line the model fitted. Panels (d,e,f) represent the quantile quantile plot for each model tested. Panels (a,d) described the single exponential model, panels (b,e) the multiple exponential model and panels (c,f) the power low model