Double tagging experiments and tag loss in *Palinurus elephas*

From: Lucía González-Vicente, David Díaz, Sandra Mallol and Raquel Goñi

Figure 1. *Palinurus elephas*. (Photo credit: D. Diaz)

In the framework of a long-term monitoring of *Palinurus elephas* (Figure 1) in the Columbretes Islands marine reserve (CIMR) (Western Mediterranean), we carried out annual tag-recapture experiments to estimate natural mortality, population size and emigration rates from the CIMR towards the adjacent fishery (Goñi et al., 2006). In addition to emigration, the loss of organisms from a tagged population may be due to: (1) natural mortality M, (2) fishing mortality F, (3) mortality related to the presence of the tag G, and (4) tag loss L. While M and F are presumably similar in tagged and untagged individuals, G and L are artifacts of the tagging method that can not be distinguished from M or F and may hinder interpretation of tag-recapture data. Tag loss in monitoring studies of *P. elephas* is not known as this species is routinely single-tagged. Here we report on the results of a double tagging experiment to estimate tag shedding rates in *P. elephas,* and explore the possible effects of timing of tagging in relation to moulting.

We double tagged 2,484 lobsters inside the CIMR during four tagging events: September 1999 and June 2000 through 2002. We used T-bar anchor tags (Hallprint®, Australia) inserted dorso-laterally on both sides of the first abdominal intersegmental membrane. A total of 1,056 lobsters were recaptured during the period 2000-2008 in the course of experimental fishing surveys inside the CIMR and commercial fishing operations outside. To estimate tag loss rates we used only data from recoveries up to three years-at-liberty, as recapture rates beyond that time were low and highly variable. In order to select recoveries having undergone a similar number of moults, we used recaptures from lobsters with times at liberty of 12 months or multiples of this period. For lobsters recaptured several times, only the first recapture was taken into account to assure data independence. The final analysis contained a total of 377 double tagged and 112 single tagged recaptured lobsters.

To estimate tag loss parameters we employed the method of Chapman et al. (1965) which was later extended by Bayliff & Mobrand (1972). Taking ρ as the immediate tag loss or Type I loss, and $\hat{L}$ as the instantaneous rate of tag loss or Type II tag loss (frequency of tag loss per unit of time), which is constant in these models (Equation 1), the probability of tag loss $\hat{P}$ (relative frequency of occurrence) was calculated with: (1) Chapman et al. model (1965) allowing only for long term tag loss, and (2) Bayliff & Mobrand model (1972) allowing for both immediate and long term tag loss (Equation 2).

$$\ln \frac{2\text{N double tag}_{ij}}{\text{N single tag}_{ij} + 2\text{N double tag}_{ij}} = -\ln \rho - \hat{L}t \quad \text{(Eq.1)}$$

where
$i = 1, 2, 3$: years at liberty
$j = 1, 2, 3, 4$: tagging events

$$\hat{P} = 1 - \rho\, e^{-\hat{L}t} \quad \text{(Eq.2)}$$

where
$1-\rho$ = immediate tag loss or Type I loss
$\hat{L}$ = instantaneous rate of tag loss or Type II loss

The probability of tag loss $\hat{P}$ was used to calculate the multinomial probabilities of the different tag-combinations: retaining two-tags $P_{DD}^{DD} = (1-\hat{P}_{ij})^2$, one-tag $P_{D}^{DD} = 2 \cdot (1-\hat{P}_{ij}) \cdot \hat{P}_{ij}$ and zero-tags $P_{0}^{DD} = (\hat{P}_{ij})^2$, and subsequently to estimate the expected probability of recapture of a lobster with two tags ($P_{DD}^{DD} / 1 - P_{0}^{DD}$), or one tag ($P_{D}^{DD} / 1 - P_{0}^{DD}$) (Adam & Kirkwood, 2001). The expected values from the fitted models with and without immediate tag loss were compared with the observed values, to decide which model produced the best fit. We explored possible differences in tag shedding related to the timing of tagging relative to moulting by comparing the observed proportions of single-tag recoveries from the September (1999) tagging event, close to moulting for males, with those observed from the June tagging events.

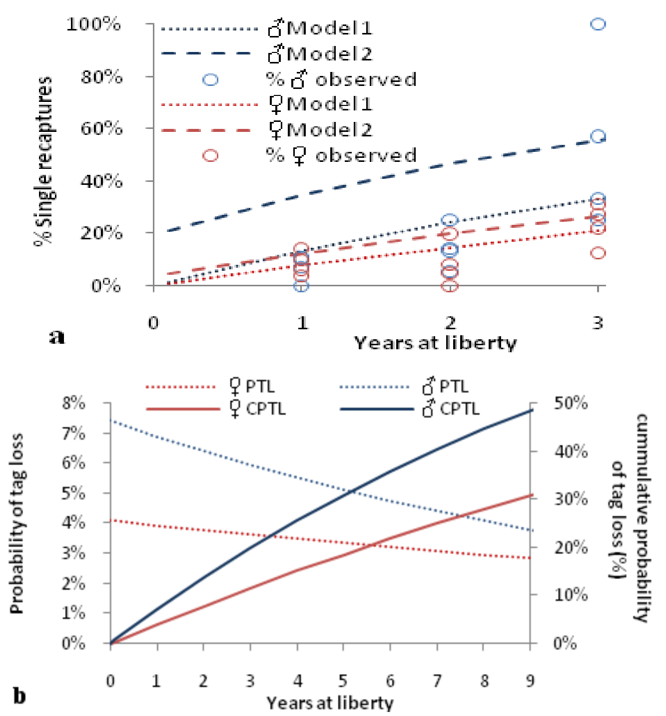

Figure 2. (a) Expected probability of recapture of single-tagged male and female *P. elephas* according to Chapman et al. (Model 1, dotted lines) and Bayliff & Mobrand (Model 2, dashed lines) and the observed percentage of single recaptures (% single/total, circles). (b) Modeled trend of the probability of tag loss (PTL,(%), dotted lines) and cumulative probability of tag loss (CPTL (%), solid lines) for both sexes.

For both sexes the model with best fit to the data over the first three-years-at-liberty was Chapman's model which assumes no immediate tag loss (Figure 2a). The estimated rate of tag loss $\hat{L}$ from that model was 7.4% $year^{-1}$ for males and 4.1% $year^{-1}$ for females (Table 1). Males are therefore almost twice as likely to lose a tag as females, probably mainly due to their greater growth rate. At this rate we forecast that 20% of male tags would be lost after 3 years, while in that period females would lose 12% of their tags (Figure 2b).

Results found for other lobster species show higher immediate mortality and shedding in those individuals tagged during the late pre-moult (Comeau & Mallet, 2003; Moriyasu et al., 1995). However, we did not observe greater tag loss one year after the autumn tagging event relative to the June tagging groups, in spite of its proximity to a male moulting period (Goñi & Latrouite, 2005) (Figure 3).

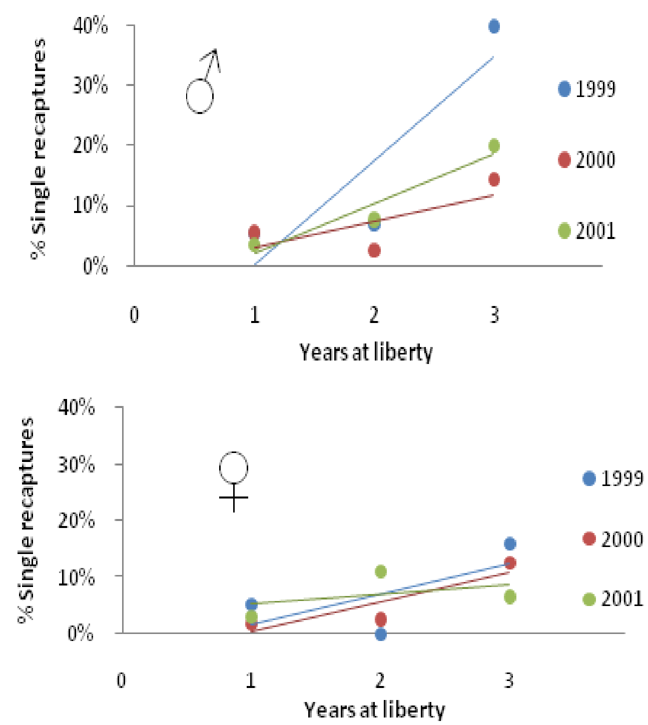

Figure 3. Observed proportion of single-tag recaptures (% single/total) for male (top) and female (bottom) *P. elephas* as a function of time at liberty for surveys 1999 to 2001; 2002 data not presented due to low recapture rates and high variability.

Our findings demonstrate that the rate of loss of T-bar anchor tags inserted dorsally in *P. elephas* in the natural environment is lower than expected on the basis of studies on other spiny lobster species (mean for sexes combined for the Chapman et al. model: 5.7% year^{-1}). In previous experiments with T-bar anchor tags inserted ventrally on *Jasus edwardsii* in the field, the tag loss was estimated at between 6-6.1% year^{-1}(♀) and 12-13.8% year^{-1}(♂) (Xiao, 2003 *cited by* McGarvey, 2004; Frusher et al.; 2008).

Also laboratory experiments on *J. verreauxi* with the same tag type inserted dorsally reached 8% year^{-1} (sex unspecified, Montgomery & Brett; 1996) (Table 2). Results of this study, when compared with previous work, suggest that tag loss may fluctuate greatly depending on species, tag type, experiment conditions, time of tagging or tagging position (Scarrat, 1970; Melville-Smith & Chubb, 1997).

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Table 1. Estimates of the instantaneous rate of tag loss $\hat{L}$ ± standard error, immediate tag retention ρ and probability of tag loss $\hat{P}$. Data from the four tagging events combined. Models with the best fit to the observed data are marked with an asterisk (*).

	Model		$\hat{L}$	intercept	r^2	inmediate tag retention ρ	probability tag loss year^{-1}	$\hat{P}$
♂	Bayliff & Mobrand	$\hat{P}=1-\rho e^{-\hat{L}t}$	0.125 ± 0.04	0.113 ± 0.08	0.52	89.30%	11.7%	
	Chapman et al	$\hat{P}=1-e^{-\hat{L}t}$	0.074 ± 0.02		0.42	100%	7.2%	*
♀	Bayliff & Mobrand	$\hat{P}=1-\rho e^{-\hat{L}t}$	0.050 ± 0.02	0.019 ± 0.04	0.43	98.08%	4.8%	
	Chapman et al	$\hat{P}=1-e^{-\hat{L}t}$	0.041 ± 0.01		0.41	100%	4.0%	*

Table 2. Tag loss rate estimates (year^{-1}) for various tag types on spiny lobsters species found in the literature. D- dorsally inserted; V- ventrally inserted.

Species	Author		Tag type	Tag loss	Tag location	Data source
Panulirus cygnus	Chittleborough, RG.	1974	Sphyrion tag	27%	D	Field
			Western rock lobster tag	30%	D	Field
Panulirus argus (juvenile)	Davis, GE.	1978	Floy FD-68B tag	45%	D	Field
Panulirus marginatus	O'Malley, JM.	2008	Streamer tag	54%	D	Field
Jasus novaehollandiae	Winstanley, RH.	1976	Dart tag	56%♂	V	Field
				41%♀	V	Field
Jasus verreauxi	Montgomery, SS. & Brett, P.A.	1996	Toggle tag	6%	D	Laboratory
			T-anchor tag	8%	D	Laboratory
			Dart tag	8%	D	Laboratory
Jasus edwardsii	McGarvey, R.	2004	T-anchor tag	12%♂	V	Field
				6%♀	V	Field
Jasus edwardsii	Frusher et al.	2008	T-anchor tag	14%♂	V	Field
				6%♀	V	Field

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*Lucía González-Vicente, David Díaz, Sandra Mallol and Raquel Goñi**
Instituto Español de Oceanografía – Centro Oceanográfico de Baleares
Muelle de Poniente s/n, 07015 Palma de Mallorca
SPAIN
* *raquel.goni@ba.ieo.es*