Amphibia-Reptilia

Performance of visual vs. software-assisted photo-identification in mark-recapture studies: a case study examining different life stages of the Pacific Horned Frog (*Ceratophrys stolzmanni*)

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Supplementary material

Table S1. Counts of *Ceratophrys stolzmanni* individuals per night.

Date	*n* of toads
21/1/2016	10
22/1/2016	2
23/1/2016	1
24/1/2016	7
25/1/2016	3
26/1/2016	2
28/1/2016	3
29/1/2016	19
30/1/2016	15
31/1/2016	12
1/2/2016	15
2/2/2016	10
4/2/2016	4
5/2/2016	20
6/2/2016	21
7/2/2016	20
11/2/2016	11

12/2/2016	6
13/2/2016	19
14/2/2016	18
15/2/2016	11
17/2/2016	4
19/2/2016	1
20/2/2016	4
21/2/2016	13
22/2/2016	2
23/2/2016	2
24/2/2016	9
26/2/2016	38
29/2/2016	41
1/3/2016	35
3/3/2016	28
5/3/2016	18
7/3/2016	6
8/3/2016	8
9/3/2016	14
10/3/2016	14
11/3/2016	25
12/3/2016	13

Total	504

Text S1. Calculation of FAR and FRR for photo-ID techniques.

Basic formulas

Following Morrison et al. (2011) and Cruickshank and Schmidt (2017), the basic formulas are:

$$FAR = \frac{N(false\ matches)}{N(non-matching\ comparisons)}$$

$$FRR = \frac{N(falsely-rejected\ matches)}{N(truly\ matching\ comparisons)}$$

N(false matches): is the number of matches made between images which were not true matching pairs.

N(falsely-rejected matches): is the number of matches between images which were true matching pairs but were not identified as such.

N(truly matching comparisons): actual number of true matches among all the comparisons made.

N(non-matching comparisons): total number of comparisons which are not true matches, defined as the total number of possible comparisons: n!/(2*(n-2)!) minus *N(truly matching comparisons)*, where n is the total number of images to be compared.

Error calculation for the first step of visual recognition

For this step, we grouped the database of images into females (*n* = 228), males (*n* = 233) and juveniles (*n* = 22). Thus, the elements for the error calculation are:

	Females	Males	Juveniles
STEP1 *N(false matches)*	0	0	0
STEP1 *N(falsely-rejected matches)*	34	32	0
STEP1 *N(truly matching comparisons)*	68	64	3
STEP1 number of possible comparisons	228!/(2*(228-2)!)=25878	233!/(2*(233-2)!)=27028	22!/(2*(22-2)!)=231
STEP1 *N(non-matching comparisons)*	25878-68=25810	27028-64=26964	231-3=228

The formulas for step 1 are:

$$FAR_{STEP1} = \frac{0}{25810 + 26964 + 228} = 0$$

$$FRR_{STEP1} = \frac{34 + 32 + 0}{68 + 64 + 3} = \frac{66}{135} = 0.49$$

Error calculation for the second step of visual recognition

This visual matching approach in the first step implicitly assumed that all individuals were assigned to the correct group with no error. This implies that no matches were missed due to different images of an individual being assigned to the wrong group. However, we discovered from the analysis with WILDID/APHIS that this assumption was not met; indeed the photo-ID analysis highlighted that in at least 30 cases photographs were assigned to the wrong group in this visual assessment process. For this reason, we run the second step one-by-one paired comparisons among images. Thus, the elements for the error calculation of the second step are:

	Total database
STEP2 *N(false matches)*	3
STEP2 *N(falsely-rejected matches)*	5
STEP2 *N(truly matching comparisons)*	150
STEP2 number of possible comparisons	483!/(2*(483-2)!)=116403
STEP2 *N(non-matching comparisons)*	116403-150=116253

The formulas for step 2 are:

$$FAR_{STEP2} = \frac{3}{116253} = 2.58E-05$$

$$FRR_{STEP2} = \frac{5}{150} = 0.03$$

Error calculation for the two-step process of visual recognition

For our study, a false acceptance occurred IF a wrong match was made in step 1 OR step 2, but a false rejection occurred IF, on the other hand, the match was missed in step 1 AND step 2. Thus, the formulas for both steps combined are:

$$FAR\ visual = 0 + \frac{3}{116253} = 2.58E - 05$$

$$FRR\ visual = \frac{66}{135} * \frac{5}{150} = 0.02$$

Error calculation for the software-assisted recognition using Wild-ID and APHIS

Calculation of error rates for Wild-ID and APHIS is straightforward because they are one-by-one paired comparisons through software. Thus, the elements for the error calculation of these techniques are:

	Wild-ID	APHIS
N(false matches)	0	0
N(falsely-rejected matches)	7	11
N(truly matching comparisons)	150	150
number of possible comparisons	483!/(2*(483-2)!)=116403	483!/(2*(483-2)!)=116403
N(non-matching comparisons)	116403-150=116253	116403-150=116253

The formulas for Wild-ID are:

$$FAR_{Wild-ID} = \frac{0}{116253} = 0$$

$$FRR_{Wild-ID} = \frac{7}{150} = 0.05$$

The formulas for APHIS are:

$$FAR_{APHIS} = \frac{0}{116253} = 0$$

$$FRR_{APHIS} = \frac{11}{150} = 0.07$$

Methods S2.b. Details of the sample for the estimates of the applicability of photo-ID to froglets.

The sample was analyzed using Wild-ID to determine the similarity scores between froglets and older stages through forced image matches: accepting the top ranked non-recapture image proposed by the software. Although the sample had to contain equal number of

images of froglets and older stages (to detect bias in matching between groups), we had to add 20 images more from older stages. This is because of the own working protocol of Wild-ID: it forces the first 20 comparisons only between the first 20 images in the database, providing too few options to choose for matching pairs. Indeed, the first match can only be done between the first two images in the database; the second match can only be done between the first three images in the database, and so on until the match number 20. Thus we added 20 images of older stages at the beginning of the database, discarded matching pairs between these first 20 images, and accepted all the matches after image 20. This is why the sample (n = 62) contained 20 images of older stages in the beginning, followed by a random mix of 21 images of recently metamorphosed froglets plus 21 images of older stages. Matches were only accepted between these 42 randomly ordered last images.