Title: M05D01-B: Identifying overfishing on Indonesian coral reefs.
Keywords: Ecosystem; coral reef; sustainable: over-fishing; statistics; case study; human impact; populations
Skills: Unpaired t-test, standard deviation and means.

Coral reefs are extremely productive ecosystems that support highly diverse and plentiful fisheries. However, the declining ecosystem health of many coral reefs has reduced the size of fisheries they are able to support. This fact, coupled with an extremely high and ever growing demand for coral reef fish is causing many global fisheries to collapse. To identify whether a fishery is being under or over-exploited, scientists will often monitor the catches of fishermen at a certain location to see how catch per unit effort (CPUE), the weight of fish caught for a set amount of effort put in, is changing over time. If catches remain stable or even increase over time, it is likely the fishery is being sustainably exploited. However, if CPUE is declining over time, it is likely that overfishing is taking place and urgent management is needed to stop the fishery collapsing completely.

The diagram above depicts a fish fence; these are a highly effective artisanal fishing structures used to capture reef fish and they are the subject of this study.

One widespread fishing technique used throughout much of the Indian and Pacific Oceans are fish fences. These are stationary structures, often up to 200m long, made of bamboo and netting. They are funnel shaped, with the opening facing the shore.

The table below shows the differences in CPUE from the Indonesian fish fences in 2005 and 2011:

	CPUE (kg per fence per day)	
Catch number	**2005**	**2011**
1	12.03	1.00
2	2.10	3.50
3	6.99	5.00
4	3.28	0.50
5	18.64	3.00
6	18.87	8.00
7	25.63	3.50
8	11.79	6.00
9	28.18	5.00
10	15.07	1.50
11	3.63	9.00
12	6.76	3.50
Mean		
Standard deviation		

Tasks and questions:

1. Your task is to apply a statistical test to the above figures to see if there is a significant difference between the 2005 and 2011 CPUE catches. Follow the outline methodology below.
2. What conclusions can be drawn from the results of this study?

Methodology for the unpaired t-test

Here we will use an un-paired t-test because, although we are studying the same broad population at two different time points, we have not used fish fences positioned in exactly the same place, and are not measuring the same exact fish, and so we cannot truly say that our samples are paired.

1. Calculate the mean CPUE in 2005 and 2011 and add these values into the able above.
2. Calculate the standard deviation for each year.

$$s = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n - 1}}$$

n = sample size

Σ = sum of

x = each value

$\overline{x}$ = mean of x

3. Determine the degrees of freedom for your test, which for an unpaired t-test is calculated using the following formula:

   $df = (n_1 + n_2) - 2$

   where n_1 is the number of replicates used in the first sample and n_2 is the number of replicates used in the second sample.

4. Now you will have everything you need to calculate a *t*-value. The formula for this is as follows:

$$t = \frac{\bar{x}_{1-} \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

   Where:
   x_1 = the mean of data set 1 (e.g. ST3)
   x_2 = the mean of data set 2 (e.g. CA2)
   s_1 = the standard deviation of data set 1
   n_1 = the number of replicates in data set 1
   s_2 = the standard deviation of data set 2
   n_2 = the number of replicates in data set 2

5. The final step is to use your *t*-value with a reference table to find the probability that there is no difference between your data sets, and therefore be able to say with confidence that there is, or is no, a significant difference. The appropriate reference table for this test is below. You need to use a 2-tail test, and then find the column with 0.05 in that row (0.05 means you are testing at a 95% confidence limit, as 1 – 0.05 = 0.95, and this is the standard level of confidence used by scientists). If you wanted to be extra confident, you could use a column with an even smaller number in it (e.g. the 0.001 column tests at the 99.9% confidence level). You then need to find the correct row for your degrees of freedom (calculated earlier), and note down the number where the correct column and row for your test meet.
6. If this number is smaller than your calculated t-test, that means you can confidently say that there is a statistical difference between your two data sets. If this number is larger than yours, you can say there is no statistical difference (at the 95% confidence level at least).

α (1 tail)	**0.05**	**0.025**	**0.01**	**0.005**	**0.0025**	**0.001**	**0.0005**
α (2 tail)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
df							
1	6.3138	12.7065	31.8193	63.6551	127.3447	318.4930	636.0450
2	2.9200	4.3026	6.9646	9.9247	14.0887	22.3276	31.5989
3	2.3534	3.1824	4.5407	5.8408	7.4534	10.2145	12.9242
4	2.1319	2.7764	3.7470	4.6041	5.5976	7.1732	8.6103
5	2.0150	2.5706	3.3650	4.0322	4.7734	5.8934	6.8688
6	1.9432	2.4469	3.1426	3.7074	4.3168	5.2076	5.9589
7	1.8946	2.3646	2.9980	3.4995	4.0294	4.7852	5.4079
8	1.8595	2.3060	2.8965	3.3554	3.8325	4.5008	5.0414
9	1.8331	2.2621	2.8214	3.2498	3.6896	4.2969	4.7809
10	1.8124	2.2282	2.7638	3.1693	3.5814	4.1437	4.5869
11	1.7959	2.2010	2.7181	3.1058	3.4966	4.0247	4.4369
12	1.7823	2.1788	2.6810	3.0545	3.4284	3.9296	4.3178
13	1.7709	2.1604	2.6503	3.0123	3.3725	3.8520	4.2208
14	1.7613	2.1448	2.6245	2.9768	3.3257	3.7874	4.1404
15	1.7530	2.1314	2.6025	2.9467	3.2860	3.7328	4.0728
16	1.7459	2.1199	2.5835	2.9208	3.2520	3.6861	4.0150
17	1.7396	2.1098	2.5669	2.8983	3.2224	3.6458	3.9651
18	1.7341	2.1009	2.5524	2.8784	3.1966	3.6105	3.9216
19	1.7291	2.0930	2.5395	2.8609	3.1737	3.5794	3.8834
20	1.7247	2.0860	2.5280	2.8454	3.1534	3.5518	3.8495
21	1.7207	2.0796	2.5176	2.8314	3.1352	3.5272	3.8193
22	1.7172	2.0739	2.5083	2.8188	3.1188	3.5050	3.7921
23	1.7139	2.0686	2.4998	2.8073	3.1040	3.4850	3.7676
24	1.7109	2.0639	2.4922	2.7970	3.0905	3.4668	3.7454
25	1.708	2.060	2.485	2.787	3.078	3.450	3.725
26	1.706	2.056	2.479	2.779	3.067	3.435	3.707
27	1.703	2.052	2.473	2.771	3.057	3.421	3.690
28	1.701	2.048	2.467	2.763	3.047	3.408	3.674