Lionfish Derbies

Methodology to Estimate Local Lionfish Density

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Bluehand

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Fishing derbies

Lionfish fishing derbies have become widely accepted among authorities, society and the public in general, as part of the strategy to fight back lionfish *Pterois volitans* invasion within the Caribbean region. These tournaments ("derbies") are intended solely to capture lionfish and are an open mode activity to the local community and even tourists. They can be exploited for the purpose of environmental education and awareness; they also concentrate intense capture in an limited area what cause a real decline in the abundance of lionfish, at least for a time. The tournaments are not frequently organized, and to achieve a high participation they should be realized in coastal towns with accessible low-cost, near or in the same urban cities. In this paper, we propose to use this activity as a source of information on absolute abundance N, on the number of individuals per area km^2 to estimate the average density D = N / A in individuals/km^2.

The magnitude of migration (immigration, and emigration), natural mortality and recruitment are kept to a minimum, almost negligible [Figure 1] because the experiment is short term (1-2 days). This satisfies the closed population assumption, during the evaluation period: the population size N changes only due to elimination of the experiment; N is supposed to remain constant for 2-3 days, except for the capture (removing) of fish *C*. The random variables are: unknown value (N, the lionfish population) and a known value (total catch *C*, number of fish). The surface A target area or coastal sector (km^2).

A carefully organized tournament will obtain data to feed a database scan. The basic data of each participant, individual or group i, include: type of boat, equipment (harpoon or hand net), number of divers, catch C_1 in number and weight (kg), and then estimate total catch *C*, in numbers of fish, tournament product $C = \sum\Sigma c_1$, plus fishing depth (m), sizes (total length, cm) and weight (kg) of fish, names of fishing sites, GPS (if possible).

Lionfish derbies and data collection

Procedures and quantitative analysis

The organizers should set the rules of a fishing tournament lionfish, and also have a format that each participant must complete mandatory, which will be recorded catch-effort data and geographic location (preferably GPS) sites used fishing.

The tournament regulations should establish which sectors are part of the target area defining the area where it will be allowed to capture lionfish in full force with a view to the award.

The target area ***A*** must have clear boundaries and signs (buoys) visible to all participants.

1) Time 1, t_1. relative density of lionfish in the target area A above using standard sampling, with band transects of fixed dimensions as the zigzag method (Green 2012).

2) Time 2, t_2. In 1-2 days, tournament total catch ***C*** in number of fish with strong effort and total catch ***C***, number of lionfish removed from the target area ***A*** during the tournament.

3) Time 3, t_3. After the derby, the same procedure is repeated and applied during time 1 (t_1), in order to obtain a second value for index of relative abundance after the derby (I_2).

Below is a table containing the required amounts, with the calculation procedures based on methods of estimating population size taken from literature. This is applied in the context of a lionfish tournament, so that the estimation of the numerical size ***N*** of lionfish population is possible to measure in the target area ***A***.

The table 1 is broken down in both the information required and the equations used in the numerical estimate of the size ***N*** of the population of lionfish.

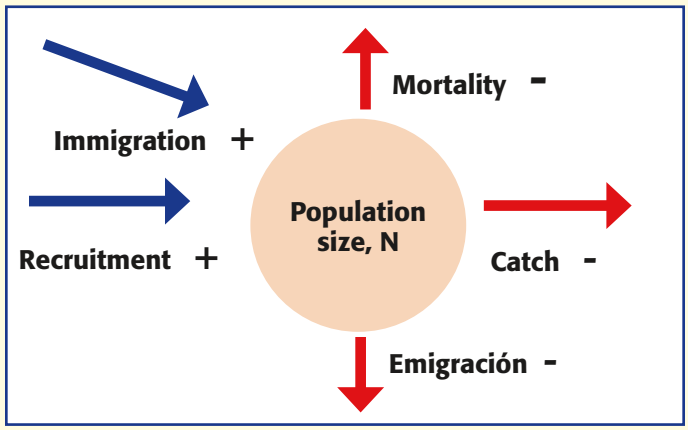


Diagram 1: Natural processes that affect a population size, N.

Table 1. Summary of main activities, the data (red) and estimate (blue) of population abundance ***N*** of lionfish, in number of individuals, occupying the target area ***A*** and the estimate of catchability coefficient $\mathbf{q_1}$, relates to the derby catch procedures. Equations for estimating ***N*** are included.

Times and activities	Data – population	Population, number
Before the derby: Time 1, t_1. Index of abundance, I_1	$I_1 = q \cdot N$	N
Derby: Time 2, t_2 Total catch C lionfish removed from area **A**		$N - C$
After the derby: Time 3, t_3 Index of abundance, I_2	$I_2 = q \cdot (N - C)$	$N - C$
Estimation of population size ***N*** and catchability coefficient ***q*** (Caughley 1977 and Seber 1982) Average density ***D*** in a selected surface area ***A*** m_2. With estimations of **n** subsites, can be obtained an average and standard deviation of density ***D*** .	$N = \frac{I_1 \cdot C}{(I_1 - I_2)}$ $q = \frac{(I_1 - I_2)}{C}$ $D = N/A$	

Ahora tienes los siguientes valores:

- I_1, index of relative abundance in time t^1; that is, the relative abundance before derby.
- *C*, total catch, in number of lionfish removed during the derby (t_2).
- index of relative abundance during t^3, or the relative abundance after the derby
- You can now estimate the total abundance ***N*** of lionfish in t_1 in the derby target fishing area.
- To estimate the lionfish population that survived immediately the tournament ***N - C***, this makes also feasible to evaluate the impact of the tournament at a local scale, such as a marine protected area (MPA).

Application, case study: Punta Langosta pier, Cozumel, Quintana Roo

The method to estimate the abundance of LF in a specific location, was applied in Cozumel Island, Mexico. Data was collected by staff of Cozumel Reef National Park, CONANP. In a sub-sector of the designated derby site at Punta Langosta Pier, the procedure was applied. The structural sections of the dock were the sampling units (n =52), and each were checked during the first sampling for relative abundance. Then accurately recorded total catch obtained in the subsector and finally there was a second sampling relative abundance.

Table 2 summarizes the relative abundance data before (t_1) and after (t_3) the derby (Figs. 1 and 2), and the total catch $C = 81$ fish caught during the derby.

The estimates, based on equations given (Table 1), of absolute abundance N before the derby, $N = 146$ lionfish are also included. With this abundance estimate prior to the derby and the total catch $C = 81$; abundance after the derby was also estimated $N - C = 65$ (=146-81). In the surface checked of 5,720 m^2 in total, density before the tournament was 255.2 fish · Ha^{-1}, while after the tournament, the density was calculated to be 113.6 fish · Ha^{-1}.

Hence, as a direct result of the derby, the impact on the local lionfish population dwelling in the structures of the Punta Langosta Pier can be measured as a numerical decrease of 55.5% (Table 2) in the size of the existing local population before the lionfish derby.

Punta Langosta pier, Cozumel, Mexico.

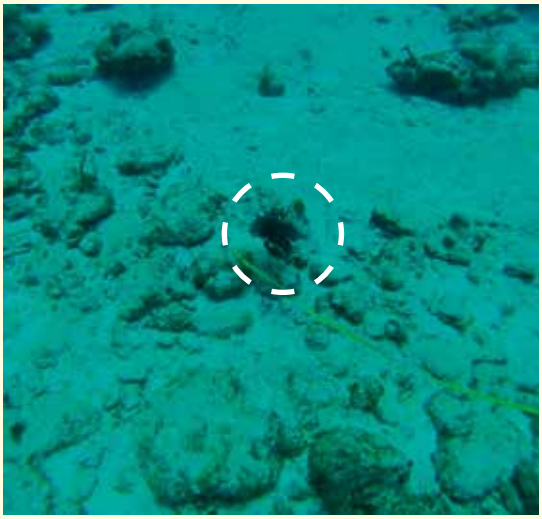
Cozumel, Mexico.

Case study: results

Table 2. Summary of estimates of lionfish population size ***N*** in the available habitat in Punta Langosta Pier. The catchability coefficient ***q*** in the capture procedures was quantified. Using relative abundance data from countdowns n=52 in structural sections of the dock, before and after the derby.

Catch or fish collected: total number and by size groups				
	Total (Number)	**< 10 cm (Number)**	**10-20 cm (Number)**	**> 20 cm (Number)**
Time 1, t1 Sampling data **/ Pre-derby**	**121**	**62** (51.24%)[a]	**47** (38.84%)[a]	**12** (9.92%)[a]
Time 2, t2 Catch data **Derby**	**81**	42[b]	32[b]	7[b]
Time 3, t3 Sampling data **/Post-derby**	**54**	**28** (51.85%)[c]	**26** (48.15%)[c]	**0** (0%)[c]
Estimates from specified method (table 1)				
Size of the population, $\hat{N}$ **Pre-derby**	**146**	**77**	**72**	**7**[d]
Coefficient of catchability, *q*	**0.8272**	**0.8095**	**0.6562**	**1.71**[d]
Size of the population, $\hat{N}$-C; **Post-derby**	**65**	**35**	**40**	**5**
Impact of the derby: reduction	**81/146= 55.5%**	**42/77=54.5%**	**32/72=44.4%**	**-**

Notes: **a)** Percentages correspondent to the fish caught per size-group during the first sampling; **b)** Assuming that 81 caught fish were distributed in same-size proportion groups as in the first sampling t1; **c)** Percentages corresponding to the fish caught per size-group in the second sampling; **d)** For this size-group, non-acceptable estimations were obtained (neither for N or q).



Lionfish observed during viusal transect

From the total catch data, regardless of size groups, using the abundance index of the first sampling I_1 =121, total catch C =81, and the index of abundance of the second survey I_2 =54; the first estimate of population size was $\hat{N}$ = 146 lionfish. In turn, the catchability coefficient ***q*** was estimated as =0.8272.

The calculations were performed using the equations from Table 1 applied to the total counts of lionfish, not considering size-groups, from the first column of Table 2. Then, the process of estimating the number of fish for each size-group was repeated to obtain estimates of absolute abundance $\hat{N}$ by size-group.

There was only one problem when estimating absolute abundance *N* for group size >20 cm, because the capture in the second survey was zero. For this group, we concluded that the method did not produce an acceptable estimate.

Case study: results

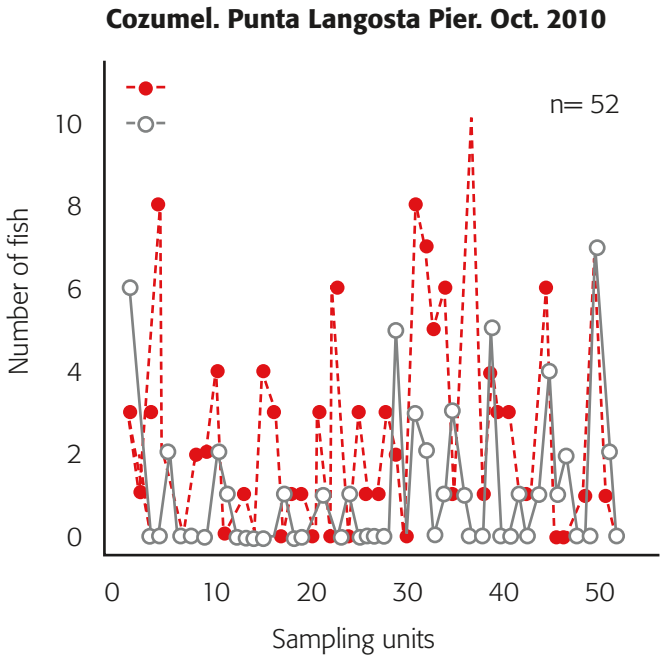


Figure 1: Counts, number of fish per sampling unit, before and after derby

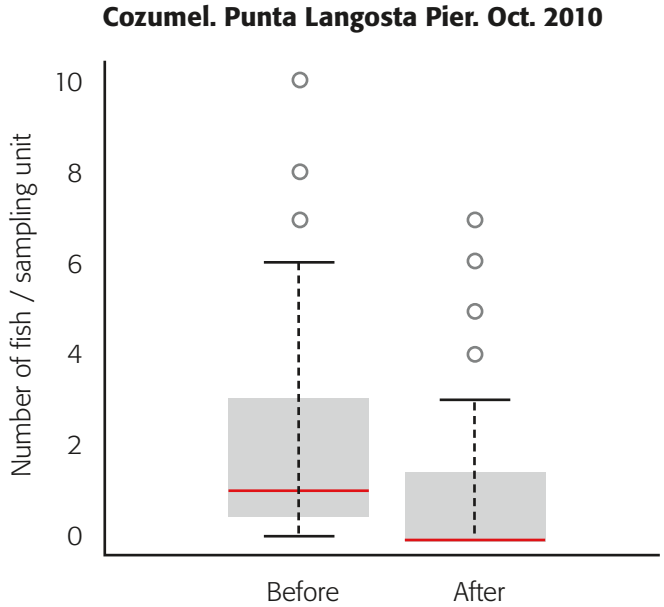


Figure 2: Comparison of counts, number of fish per sampling unit, before and after derby. The median corresponds to the horizontal line inside the boxes.

Dano Pendygrasse

Removal experiments: successive catches in a short period of time

In order to estimate the population size or abundance ***N*** of lionfish dwelling in an area previously defined, we present a methodological alternative, that is simple and feasible to be developed by a team formed by MPA´s staff, scientists, users: fishers, dive-guides, NGOs partners and volunteers.

Jomlines

This method involves depletion experiments, with successive removals applied in a short period of time, i.e., two to five successive catch occasions applied in a set of stations or sub-areas within a selected target area. In this case it is particularly critical that the experiment takes place in the short-term, and that the whole series of successive catches be applied within five to seven days. Here we consider a week: seven days, as the maximum duration of the experiment, with two to five successive occasions of fish removals.

Preferably, in each time or occasion *t* must be applied the same amount of effort in number of divers or diver-number of hours invested, which corresponds to a certain number of lionfish being caught each time *t*. However, this method works well when the effort is variable, as long as you rigorously record the amount of fishing effort applied in every occasion. So throughout the experiment conducted in target area *B* , shall be registered f_t sampling effort applied, and catch in numbers of fish c_t obtained each time *t*. It is considered that the catch per unit effort, defined as $\frac{c_t}{f_t}$ is an index of abundance of lionfish, which has a direct relationship with abundance *N*, from equation $\frac{c_t}{f_t} = q \cdot N$.

In practice, we define a target area or sector *B* , where we apply a specified amount of fishing effort for two to five consecutive days, or, where there will be two five successive revisions or "dives" to review systematically the target area, to remove as many lionfish as possible. This is a key assumption of the method: that the catch or removal due to fishing is big enough to cause a detectable decrease in relative abundance indices calculated each time or occassion *t*.

At the end of the successive experimental removals, we will have the information needed to apply the Leslie´s method (Ricker 1975, Caughley 1977, Seber 1982) that allows to estimate the population size *N*, the number at the beginning of the experiment and the proportionality factor q_1, between catch per unit effort and stock abundance.

The Leslie´s method for closed-population, according to the notation by Ricker (1975), is to fit a simple linear regression model Y *vs*. x, where the explanatory variable x is the cumulative catch K_{t-1} just before the occasion t, and the response variable Y corresponds to the abundance index $\frac{c_t}{f_t}$ measured at the time t. Once obtained the regression coefficients: intercept *a* , and slope *b* ; these values are used to yield estimates of initial population size N_o in lionfish numbers at the beginning of the experiment, the

population size of lionfish that we are interested in estimate as well as the catchability coefficient q , which relates the total abundance with the abundance ***N*** index.
Leslie's model is a linear regression Y vs. x, where

$Y = \frac{c_t}{f_t}$ y $x = K_{t-1}$, after the formula $\frac{c_t}{f_t} = a - b \cdot K_{t-1}$, according to the following formula $\frac{c_t}{f_t} = a - b \cdot K_{t-1}$, with a the intercept, and ***b*** the slope. This is equivalent to:

$$\frac{c_t}{f_t} = q \cdot N_o - q \cdot K_{t-1}$$

In this way, the value of b is an estimate of the catchability coefficient q , $b = q$; while the quotient between the intercept a and the slope b yields an estimate of the population size N_o at the beginning of the experiment, according to $N_o = {}^{a}/_{b} \cdot$.

One option is to consider five occasions, either in days, a sequence of five "dives" or intensive checking visits through SCUBA diving, one in the morning and one in the afternoon, avoiding notorious differences in environmental conditions between the morning and afternoon, since these could affect catchability q – according to chances of detection and capture by divers, as well as the behavior of the lionfish.

It is worthy to mention that the spatial scale at which the Leslie method has the ability to provide acceptable results. Again, the criteria used for delimitation of the target area depends on the particular goals for managing the location in question, whether or not as part of an MPA, and according to the purpose of assessing the lionfish population.

In some cases several small sites could be selected, say a surface area of 0.5 to 1 hectare as a set of sub-target areas. It is also possible to choose an intermediate situation, when the purpose is to estimate the abundance of lionfish in a reef area ranging 5 to 10 hectares. In the first two cases, it is possible that the application of the Leslie´s method will yield acceptable results. In contrast, at larger spatial scales, for example when it is an entire bay, a target area whose surface is close to half a large MPA area, or to entirely cover a small MPA, the application of Leslie´s method involves intractable practical difficulties.

Table 3. Summary of the data needed to estimate abundance ***N***, in number of lionfish in a particular location ***B***, using a short term experiment of successive removals in B. Included are the equations to calculate ***N*** considering five occasions to catch lionfish in ***B***

Occasion, checking t	**Catch, in number c_t**	**Effort amount f_t**	**Catch per unit effort, c_t / f_t**	**Cumulative catch before occasion t, K_{t-1}**
1	C_1	f_1	c_1 / f_1	0 (by definition)
2	C_2	f_2	c_2 / f_2	c_1
3	C_3	f_3	c_3 / f_3	$c_1 + c_2$
4	C_4	f_4	c_4 / f_4	$c_1 + c_2 + c_3$
5	C_5	f_5	c_5 / f_5	$c_1 + c_2 + c_3 + c_4$

Leslie method (Ricker 1975, Caughley 1977, Seber 1982).

Linear regression of $Y = \frac{c_t}{f_t}$ contra $x = K_{t-1}$

$\frac{c_t}{f_t} = a - b \cdot K_{t-1}$ a is the intercept, b is the slope

$\frac{c_t}{f_t} = q \cdot N_0 - q \cdot K_{t-1}$ Hence, $b = q$; $y = N_0 = \frac{a}{b}$

Final Remarks

In this paper we reviewed two simple methods potentially useful as part of the control instruments against the invasion of lionfish in the Caribbean region in general and the Mesoamerican Reef in particular. We have incorporated the fishing tournaments and their popularity with the multi-purpose source of information for estimating locally lionfish density. Moreover, we also explained the depletion experiments application of successive catch to estimate the density of lionfish in specific locations. Both fishing tournaments and depletion experiments can be seen as complementary methods. Tournaments are more inclusive, ideal for coastal communities of easy access, while depletion experiments are more suitable for trained personnel in remote and inaccessible areas. We recommend checking procedures of Borchers et al. (2002) to incorporate the calculation of confidence intervals for density estimates.

In the Mesoamerican Reef region, the co-authors of this paper participated in collaborative efforts aimed at implementing these methods, as well as in the organization of workshops to exchange ideas and experiences in the region.

For more information, visit our webpage:
http://www.marfund.org/sp/new_projects/introduction.html

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Partners

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