Hatchling production estimation using Richards functions

This is a preliminary analysis and results may change in the future.

In this document, I describe the steps I used to estimate the number of annual hatchling production from several observations during each nesting season at six sectors (2014R, 2017R, North, South, West, 2019R) on Raine Island. In a separate analysis, I fitted various functions to hatchling counts and found that using modified Richards functions (Girondot et al. 2007) provided the most precise estimates. Results of the comparison of these models are available upon request.

Modified Richards equation by Girondot et al. (2007)

In this approach, I used the model described by Girondot et al. (2007). It has two symmetrical functions that are connected at the peak of nesting.

The function has the following form:

M1 = (1 + (2 * exp(K) - 1) * exp((1/(-S)) * (P - d))) ^ (-1/exp(K))

M2 = (1 + (2 * exp(K) - 1) * exp((1/S) * (P - d))) ^ (-1/exp(K))

N = min_N + (max_N - min_N) * (M1 * M2), where

d is the number of days from the beginning of nesting season,

S defines the "fatness" of the function (S > 0),

K > 0 defines the "flatness" at the peak of the function (K > 0),

P defines where the peak is relative to the range of d, where min(d) < P < max(d),

min_N is "the basal level of nesting outside the nesting season" and,

max_N » min_N

This model was fitted to observed hatchling counts per 100 m in each sector and estimated parameters (S, K, P) and their uncertainties were used to compute the total number of hatchlings and its uncertainties from each sector.

Although no formal goodness-of-fit test was conducted, the functions fit qualitatively reasonable to the data (Figure 1). The fitted function, then, was used for each combinatin of a sector and a season to estimate the number of hatchlings per 100 m. Because the parameters of the function were shared among sectors, estimates were available even when there were limited data (this extrapolation is not presented in this report).

Assuming that observed counts per 100 m represent the entire sectors, we extrapolated the estimated numbers to the entire sectors (Figure 2).

2014 The total number of hatchlings produced in 2014 ranged from `248,209` (95% CI = [`177,624 - 314,545`]) in the `2014R` sector to `549,757` (95% CI = [`393,832 - 698,092`]) in the `North` sector (Tables 1, 2, 3).

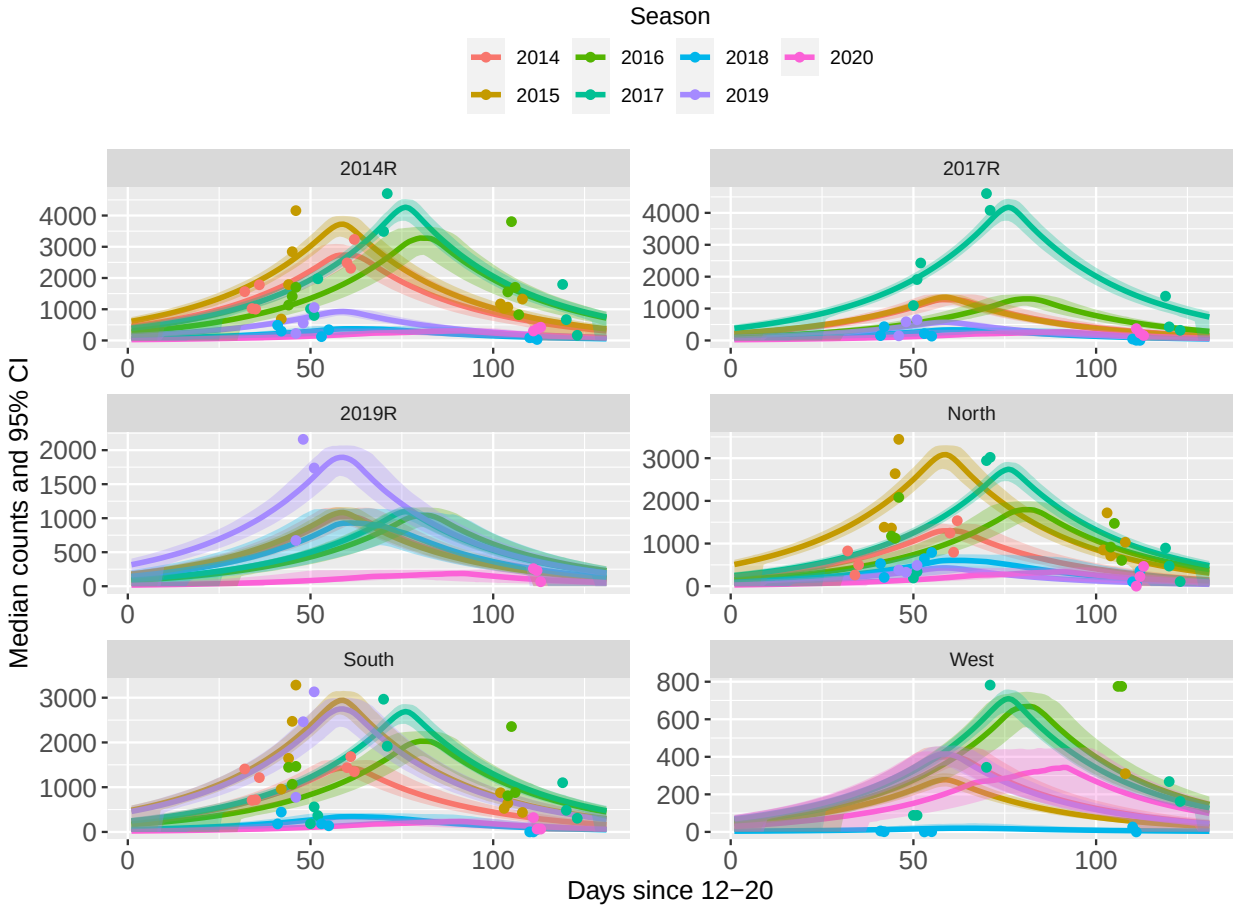

Figure 1: Figure 1. The fitted functions (medians in solid lines and their 95% CIs in shaded areas) and observed numbers of hatchlings (dots) per 100 m at six sectors.

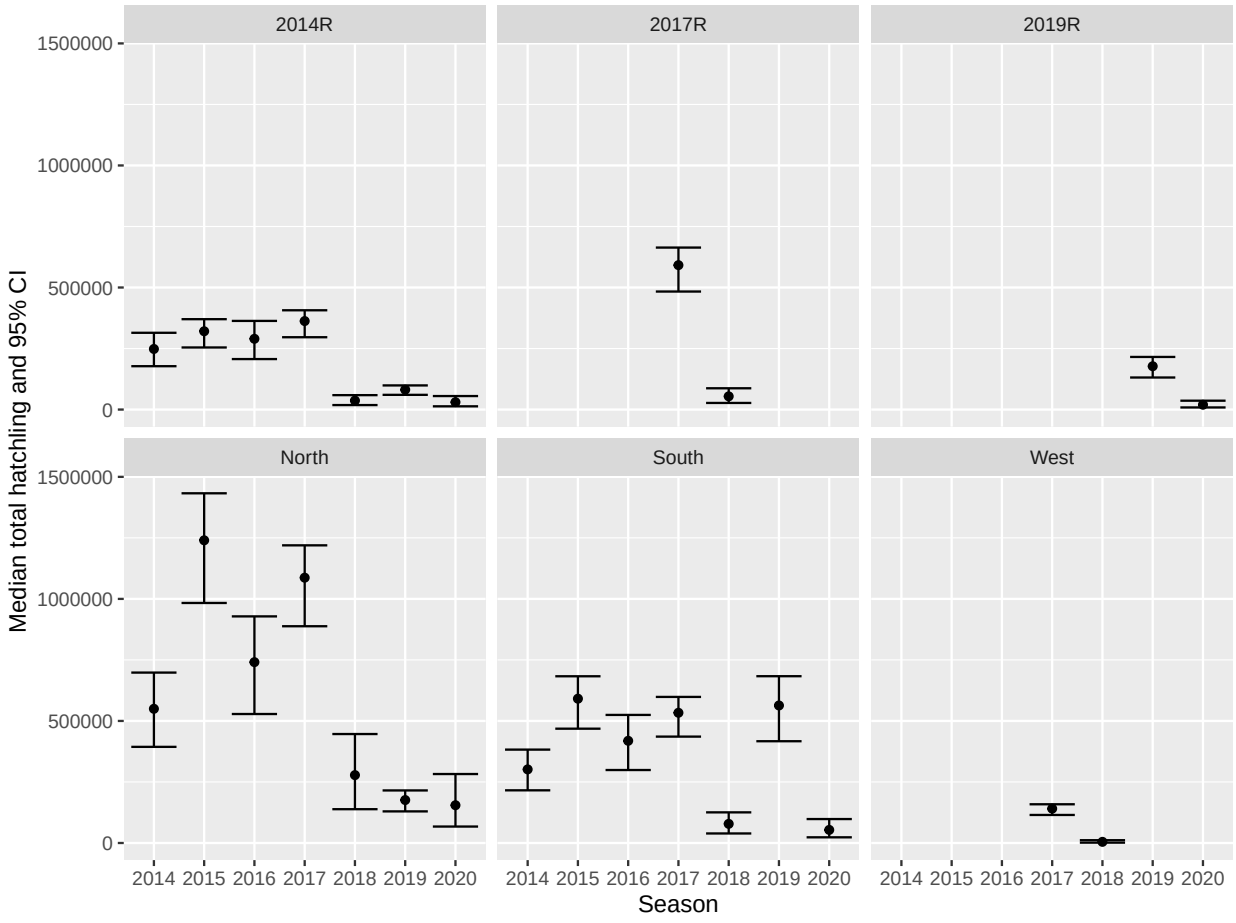

Figure 2: Figure 2. Extrapolated total hatchling abundance at six sectors using estimated Richards function. Year-sector combinations with little or no data were excluded from computing the hatchling abundance.

2015 The total number of hatchlings produced in 2015 ranged from 320,805 (95% CI = [254,344 - 370,235]) in the 2014R sector to 1,240,033 (95% CI = [983,255 - 1,432,546]) in the North sector (Tables 1, 2, 3).

2016 The total number of hatchlings produced in 2016 ranged from 289,880 (95% CI = [206,844 - 363,116]) in the 2014R sector to 740,867 (95% CI = [528,383 - 928,332]) in the North sector (Tables 1, 2, 3).

2017 In 2017, they ranged from 140,803 (95% CI = [114,807 - 158,599]) in the West sector to 1,086,872 (95% CI = [887,919 - 1,219,368]) in the North sector (Tables 1, 2, 3).

2018 In 2018, they ranged from 4,763 (95% CI = [1,414 - 11,438]) in the West sector to 278,117 (95% CI = [138,422 - 446,366]) in the North sector (Tables 1, 2, 3).

2019 In 2019, they ranged from 81,484 (95% CI = [60,330 - 98,875]) in the 2014R sector to 563,383 (95% CI = [416,861 - 683,258]) in the South sector (Tables 1, 2, 3).

2020 In 2020, they ranged from 19,809 (95% CI = [8,624 - 36,355]) in the 2019R sector to 154,732 (95% CI = [67,365 - 282,517]) in the North sector (Tables 1, 2, 3).

Table 1: Median estimated total hatchling production per sector based on modified Richards' equations.

	2014	2015	2016	2017	2018	2019	2020
2014R	248,208	320,805	289,879	362,527	36,824	81,483	30,314
2017R	NA	NA	NA	591,652	54,230	NA	NA
2019R	NA	NA	NA	NA	NA	177,493	19,809
North	549,756	1,240,032	740,867	1,086,871	278,116	175,918	154,731
South	301,578	591,138	418,652	533,474	78,403	563,382	53,638
West	NA	NA	NA	140,803	4,762	NA	NA

Table 2: Lower credibility limits of estimated total hatchling production per sector based on modified Richards' equations.

	2014	2015	2016	2017	2018	2019	2020
2014R	177,623	254,343	206,844	296,273	18,388	60,330	13,205
2017R	NA	NA	NA	483,546	27,104	NA	NA
2019R	NA	NA	NA	NA	NA	131,343	8,623
North	393,831	983,255	528,382	887,919	138,422	129,457	67,364
South	215,755	468,312	298,896	435,794	38,994	416,860	23,214
West	NA	NA	NA	114,807	1,413	NA	NA

Table 3: Upper credibility limits of estimated total hatchling production per sector based on modified Richards' equations.

	2014	2015	2016	2017	2018	2019	2020
2014R	314,545	370,235	363,116	406,721	59,008	98,875	55,275
2017R	NA	NA	NA	663,578	87,227	NA	NA
2019R	NA	NA	NA	NA	NA	215,503	36,354
North	698,092	1,432,546	928,331	1,219,367	446,366	215,312	282,517
South	382,495	683,030	524,621	598,429	125,517	683,257	98,032
West	NA	NA	NA	158,599	11,438	NA	NA

Effects of reprofiling

To determine the effects of re-profiling the beach, the number of estimated hatchlings per 100 m was compared between 2014R and the South sector and between 2017R and the South sector. The re-profiled areas (2014 and 2017) experience the same environmental effects and nesting activities as the South sector.

Table 4: Median estimated total hatchling production per 100 m based on modified Richards' equations.

	2014	2015	2016	2017	2018	2019	2020
2014R	165,472	213,870	193,253	241,685	24,549	54,322	20,209
2017R	NA	NA	NA	236,661	21,692	NA	NA
2019R	NA	NA	NA	NA	NA	110,933	12,380
North	78,537	177,147	105,838	155,267	39,731	25,131	22,104
South	86,165	168,897	119,615	152,421	22,401	160,966	15,325
West	NA	NA	NA	40,229	1,361	NA	NA

Table 5: Lower credibility limits of estimated hatchling production per 100 m based on modified Richards' equations.

	2014	2015	2016	2017	2018	2019	2020
2014R	118,416	169,562	137,896	197,515	12,259	40,220	8,804
2017R	NA	NA	NA	193,418	10,841	NA	NA
2019R	NA	NA	NA	NA	NA	82,089	5,389
North	56,262	140,465	75,483	126,846	19,775	18,494	9,623
South	61,644	133,803	85,399	124,513	11,141	119,103	6,633
West	NA	NA	NA	32,802	404	NA	NA

Table 6: Upper credibility limits of estimated hatchling production per 100 m based on modified Richards' equations.

	2014	2015	2016	2017	2018	2019	2020
2014R	209,696	246,823	242,077	271,147	39,339	65,916	36,850
2017R	NA	NA	NA	265,431	34,891	NA	NA
2019R	NA	NA	NA	NA	NA	134,689	22,722
North	99,727	204,649	132,619	174,195	63,767	30,759	40,360
South	109,284	195,151	149,892	170,980	35,862	195,216	28,009

	2014	2015	2016	2017	2018	2019	2020
West	NA	NA	NA	45,314	3,268	NA	NA

The reprofiled sectors consistently produced more hatchlings than the unmodified South sector over the four year period (Tables 4, 5, 6). The increase in hatchling productions in the 2014R sector ranged from `1.02` (95% CI = [`1.01 - 1.03`]) in `2017` to `2.74` (95% CI = [`2.70 - 2.81`]) in `2015` (Table 7).

Table 7: Amount of increase in hatchling productions at the 2014R sector compared with the South sector.

	2014	2015	2016	2017	2018	2019	2020
2.5%	2.09	2.70	2.46	1.01	1.04	1.55	1.03
50%	2.14	2.74	2.51	1.02	1.13	1.62	1.14
97.5%	2.18	2.81	2.56	1.03	1.22	1.70	1.25

The increase in hatchling productions in the 2017R sector ranged from `0.656` (95% CI = [`0.649 - 0.663`]) in `2017` to `1.83` (95% CI = [`1.71 - 1.96`]) in `2018` (Table 8).

Table 8: Amount of increase in hatchling productions at the 2017R sector compared with the South sector.

	2017	2018	2019	2020
2.5%	0.65	1.71	0.70	1.14
50%	0.66	1.83	0.75	1.25
97.5%	0.66	1.96	0.81	1.37