Giant Trevally (*Caranx ignobilis*) aggregation dynamics in the Ponta do Ouro Partial Marine Reserve: Implications for management

By

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1.1. Introduction

Giant trevally (*Caranx ignobilis)* are large predatory fish (170 cm TL, 87 kg) with a global distribution throughout tropical and warm temperate oceans. They are relatively fast growing, gonochoristic broadcast spawners, first reaching sexual maturity at approximately 3.5 years of age. As top predators, they play an important ecological role within their respective marine community and are also prized by recreational fishermen for their strong fighting abilities. Although the global commercial fishery for giant trevally in developed countries has declined, there is a significant recreational demand for this species throughout its distribution.

Giant trevally have received considerable research attention in the Pacific Ocean but little information exists on this species in the Indian Ocean. Understanding the spatial and temporal characteristics of fish aggregations has important ecological and management implications. Giant trevally are known to form spawning aggregations, typically in

summer during full moon, but little is known about the aggregation dynamics of these fish or their vulnerability to fishing during aggregation events. Thus, the aim of this study was to use long-term (5 year) observational data to describe the occurrence and persistence of a large aggregation of adult giant trevally within the Ponta do Ouro Partial Marine Reserve (PPMR) and to discuss relevant potential management implications.

1.2. Results

1.2.1. Observations

The giant trevally aggregation observed within the PPMR represented a spatially and temporally predictable aggregation of conspecific fish that occurred in densities considerably greater than typically observed. Over the five-year observational period (2010-2014), an aggregation of adult giant trevally was recorded 27 times at the Pinnacle reef (Fig. 1) over multiple years (2010-2014) between November (n = 16) and December (n = 7) and for one year (2014), in February (n = 4) (Table I). The seasonal timing of the aggregation was consistent with previously reported giant trevally aggregations and the colour dimorphism exhibited by some mature individuals within the shoal was characteristic of giant trevally spawning aggregations in other localities (Fig. 2). Specifically, the seasonal longevity (2 – 3 months) of the aggregation and life history of the giant trevally are consistent with transient aggregative spawning fish species.

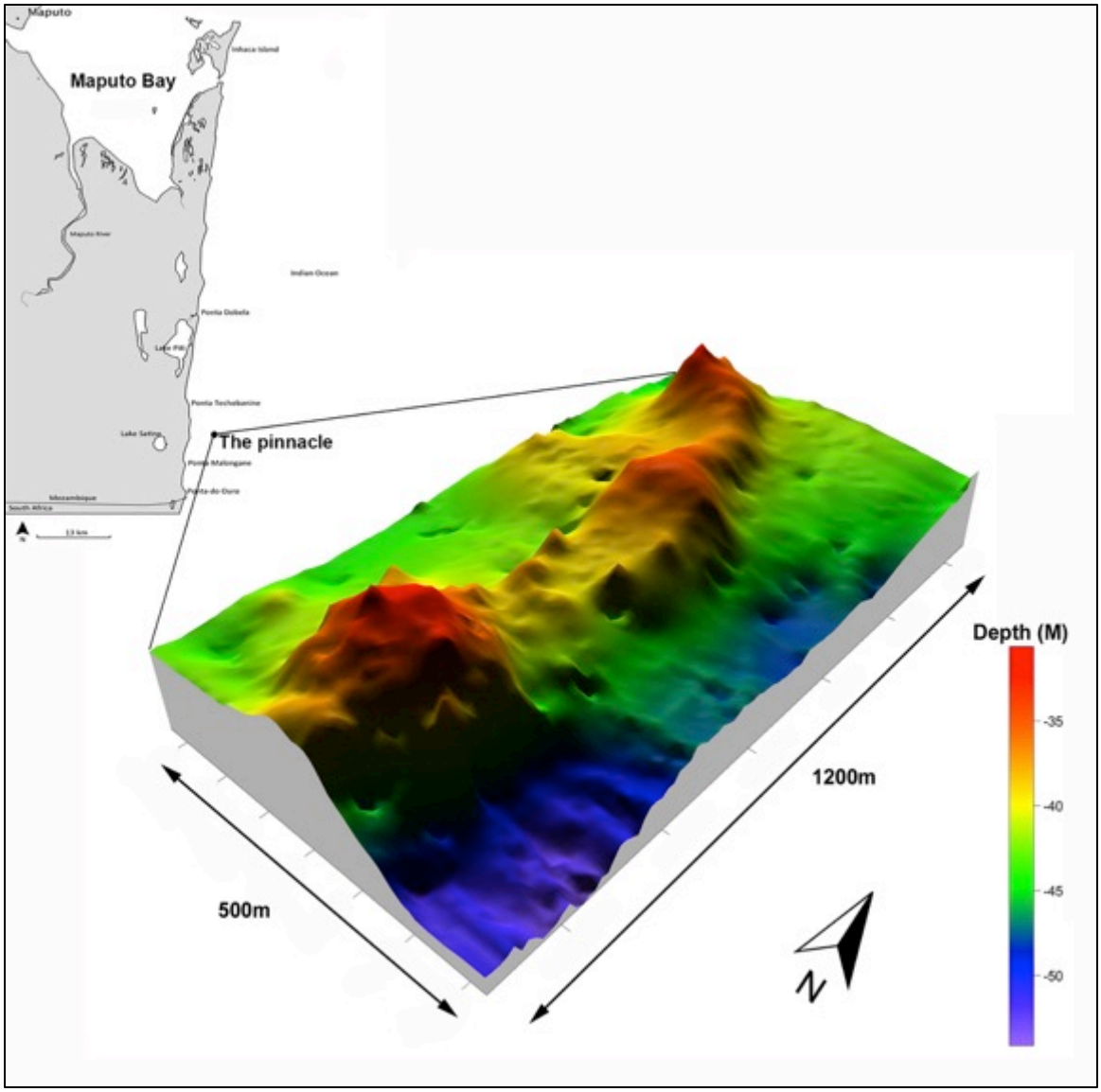

Fig. 1. A bathymetric map showing the Pinnacle reef located within the southern extent of the PPMR, approximately 3.7km offshore (S26° 44.934' E32° 56.083'). The giant trevally aggregation was observed throughout the extent of the Pinnacle reef (northern and southern sections) and appeared to be strongly associated with only this reef.

Table I. Tally of the observations conducted at the study site between January 2010 and December 2014 (Obs. denotes the number of observational dives, GTs. denotes the number of times the giant trevally aggregation was sighted).

	2010		**2011**		**2012**		**2013**		**2014**		**Total**	
	Obs.	GTs.	Obs.	GTs.	Obs.	GTs.	Obs.	GTs.	Obs.	GTs.	Obs.	GTs.
January	3	0	6	0	4	0	4	0	5	0	22	0
February	13	0	0	0	1	0	0	0	11	4	25	4
March	1	0	0	0	5	0	0	0	0	0	6	0
April	9	0	0	0	2	0	0	0	0	0	11	0
May	6	0	0	0	0	0	0	0	0	0	6	0
June	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	5	0	0	0	0	0	5	0
October	0	0	0	0	0	0	0	0	0	0	0	0
November	5	1	4	3	5	3	6	5	4	4	24	16
December	5	0	2	2	4	1	3	3	1	1	15	7
Total	42	1	12	5	26	4	13	8	21	9	114	27

Figure 2. An image showing colour dimorphism and pairing exhibited between adult male and female giant trevally within the aggregation.

1.2.2. Lunar cycle

Lunar phase appeared to have an influence on the giant trevally aggregation, with observations made more frequently between the first and third quarters of the lunar cycle (Fig. 3). However, the results from Rao's spacing test did not support the hypothesis that the data were unevenly distributed or biased relative to a particular lunar cycle ($P > 0.05$).

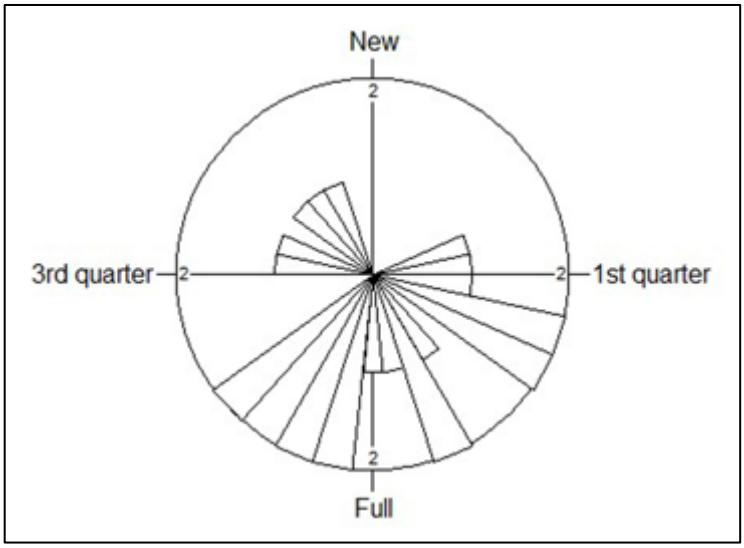

Figure 3. A rose diagram showing the frequency distribution of giant trevally aggregation sightings at the study site relative to the lunar cycle represented as new, 1st quarter, full and 3rd quarter.

1.2.3. Fish counts

Three techniques (MaxN, Running counts and Sphere volume estimates) were employed to estimate the abundance of giant trevally in the aggregation using video of the aggregation over multiple years. The MaxN approach provided maximum counts per dive ranging from 304 to 451 individuals in a single frame (mean ± SD = 390 ± 58) (Table II). The maximum count of 451 was recorded during the December 2011 observation dive (Fig. 4).

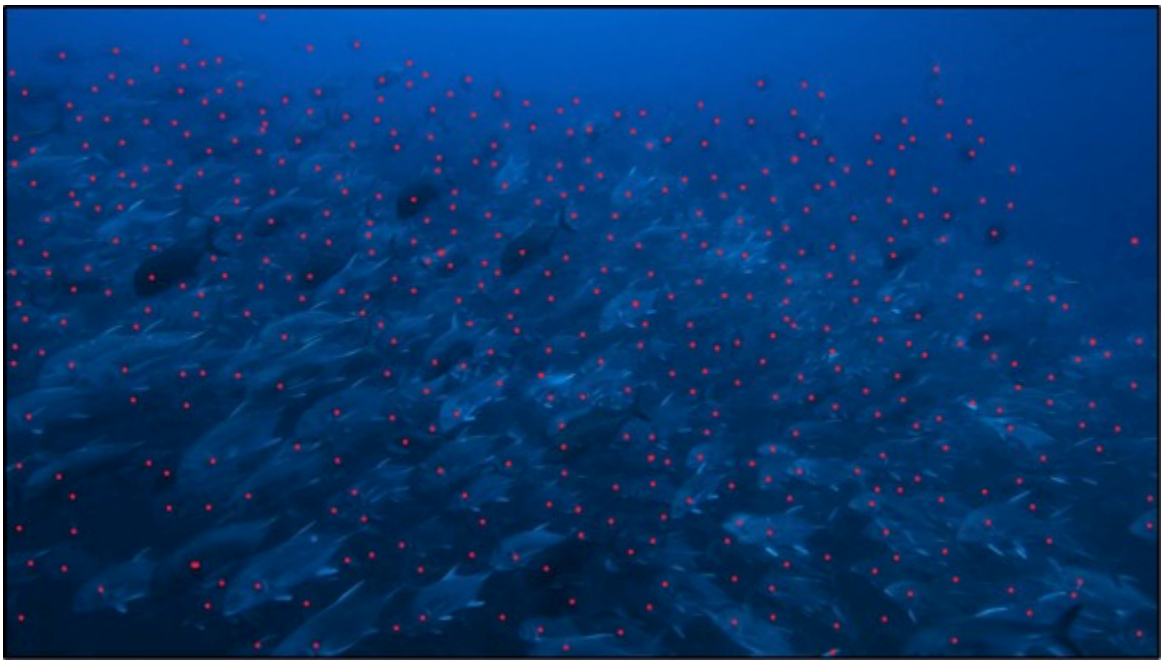

Figure 4: Video frame showing the MaxN count of the giant trevally aggregation at the study site recorded during December 2011. Each dot represents an individual fish count (n = 451).

The running counts presented higher estimates of abundance, as well as greater variability among observation dives (Table II). These estimates were considerably higher for every dive than the associated MaxN counts, and ranged from 455 to 1 329 (mean ± SD = 806 ± 315) individual fish. The maximum running count of 1 329 fish was also recorded in December 2011, from a 33.73 s video clip, which ended with the frame containing MaxN on this dive (see Fig. 4).

Table II: Abundance estimates of giant trevally at the study site derived from three different methods (MaxN, Running count and Volume count) based on annual underwater video recordings.

Year	Month	MaxN	Running count	Volume count
2011	December	451	1 329	3 054
2013a	December	349	612	1 767
2013b	December	358	676	2 145

2013c	November	449	955	2 145
2014a	December	304	No suitable segment	2 145
2014b	December	401	455	4 189
2014c	December	445	638	2 145
Mean		390	806	2 513
SD		58	315	837

The sphere volume estimates ranged from 1 767 to 4 189 fish (shoal "diameters" ranged from 15 to 20 fish) (Table II). These estimates were substantially greater than those obtained with the MaxN counts and the running counts. The maximum of 4 189 fish was estimated from an observation dive in December 2014.

Although none of the abundance estimates are completely accurate, this is the first attempt to use standardized methods to quantify the abundance of giant trevally within an aggregation. Taking into consideration the various pitfalls of each abundance estimate method, the aggregation of adult giant trevally reported on in this investigation still represents one of the largest ever recorded with annual estimates of up to 4 189 individual fish.

1.3. Management implications

If the giant trevally aggregation recorded in this investigation is a transient spawning event, as the evidence suggests, individual fish may migrate from substantial distances along the coast to take part in the aggregation and represent a major share of the southwest Indian Ocean population's annual reproductive effort. The migrations associated with the movements of transient aggregating species may also have important implications for energy flows between foraging and aggregating sites. Additionally, the spatial and temporal increase in abundance of these species may facilitate various unique trophic level interactions. Indeed, observational evidence at the aggregation site reported

in this study suggests that bull sharks (*Carcharhinus leucas*) are associated with the giant trevally aggregation and increase in abundance within the region during the presence of the aggregation.

Due to the ecological importance and vulnerability of predictable fish aggregations to recreational and commercial fishing, their sustainable management should be a priority. No take zones within MPAs that incorporate aggregation sites or seasonal fishery closures during periods of aggregation may both be effective conservation tools if the enforcement of such regulations is possible. However, the catchability of the fish within the aggregation also needs to be considered as some species do not feed during spawning aggregations and thus fishery closures may be unwarranted. Additionally, fish may also be subject to high fishing mortality on migration routes to and from aggregation sites and the extent of the fish's functional migration area also needs to be considered. If a large proportion of the fish taking part in the aggregation event described in this study are from South Africa (as is likely), future management should also ensure congruent trans-frontier conservation policy aimed at securing the sustainability of the aggregation event.

Thus, it is recommended that at this stage a priority should be placed on future research aimed at answering questions related to the home range of fish within the aggregation, migration routes of fish taking part in the aggregation, the aggregations seasonal occurrence and characteristics and the susceptibility to recreational angling. It is not yet clear if fish at the aggregation are being targeted by recreational fishermen, although there is some evidence to suggest that fishing operators in Ponta do Ouro do know about the aggregation and have targeted fish there previously. However, due to the presence of bull sharks associated with the aggregation, hooked fish are almost always lost. This is concerning as there could be a high mortality associated with recreational fishing at the aggregation site that goes under-reported to management. Thus, the aim of future research should be to determine the vulnerability of fish at the aggregation to recreational angling. It is also critical that knowledge of the aggregation be kept classified in order to avoid potential commercial fisheries from targeting and poaching fish at the aggregation where they may be highly susceptible to commercial fishing gear.

1.4. Future research

Future research will be aimed at addressing the gaps in our knowledge regarding the aggregation characteristics, home range, functional migration area, and susceptibility to fishing of fish within the aggregation. In order to do this, ongoing monitoring at the Pinnacle reef between November and January each year will be conducted and the aggregations presence will be recorded when possible. We plan to use structured video surveys and stereo-videography to improve current abundance estimates and to determine the biomass of the aggregation. Additionally, acoustic telemetry will be used to investigate the presence of fish at the Pinnacle reef during the aggregation and to determine their movement patterns. Fish at the aggregation will be caught and surgically implanted with acoustic tags which will be monitored using the existing receiver array at the Pinnacle and adjacent Mozambique / South African border, as well as the larger coastal network of receivers throughout southern Africa and, finally, using additional receivers within the PPMR deployed only between November and January each year. This research is planned to take place between November 2015 and January 2016.