Ecology of wild and cultured juvenile *Trochus niloticus* relevant to the use of juveniles for population enhancement

Laura Liliana CASTELL PEREZ, Lic., MA

Thesis submitted for the degree of Doctor of Philosophy in the Department of Zoology at James Cook University of North Queensland, Australia.

March 1996

STATEMENT OF ACCESS

I, the undersigned, the author of this thesis, understand that James Cook University of North Queensland will make it available for use within the University Library and, by microfilm or other means, allow access to users in other approved libraries. All users consulting this thesis will have to sign the following statement:

> In consulting this thesis I agree not to copy or closely paraphrase it in whole or in part without the written consent of the author; and to make proper public written acknowledgement for any assistance which I have obtained from it

Beyond this, I do not wish to place any restriction on access to this thesis.

.... 11 November 96

STATEMENT ON SOURCES

DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

.... 11 November 96

ABSTRACT

Natural stocks of the topshell *Trochus niloticus* L. (hereafter referred to as *Trochus* and trochus) have decreased significantly as a result of commercial fishing. This has led to the release of hatchery-reared juveniles being viewed as a potential tool to enhance populations. However, most experimental releases have resulted in low survival rates, with little known of the reasons for these results and how to improve them. The objectives of this study were to understand better the ecology of juvenile *Trochus* on the reef and to use this information to identify factors affecting their survival and growth.

Density, natural distribution, habitat characteristics and growth of juvenile *Trochus* and other gastropods on the intertidal reef flat at Orpheus Is., Australia, were sampled over a two-year period. *Trochus* between 1.5 mm and 62 mm shell width (SW) were found across the reef flat, but were most abundant in the middle section of the reef, 50-150 m off shore. There was no evidence of a size gradient. Mean density of *Trochus* was 0.178m^{-2} in 1993 and 0.115 m^{-2} in 1994. *Trochus* occurred in groups of 2-4 per m^2 more frequently than expected by random, but higher densities were very rarely observed. As *Trochus* size increased, there was a change from tending to occupy small rubble to occupying rock and coral bench, and from shallow to deeper pools. Growth rates estimated by progression of modal size classes ranged between 2.3 and 2.6 mm.$month^{-1}$.

The interaction between juvenile *Trochus* and three common invertebrate predators, the portunid crabs, *Thalamita admete* and *T. stimpsoni*, and the carnivorous gastropod, *Thais tuberosa*, were examined. Interactions with crabs were studied in the laboratory. The size of trochus eaten increased with crab size, but larger crabs continued to eat the smallest trochus offered. Crabs also attacked relatively large trochus, up to 24 mm SW with low probability of success. The combined action of *Th. admete and Th. stimpsoni* may have a significant effect on the survival of *Trochus* < 20 mm SW, but mainly on smaller individuals (< 13 mm SW). Crabs responded to an increase in trochus density from 5 to 30 individuals.$container^{-1}$ by increasing their predation rate so that the proportion of trochus eaten after 24 h was significantly greater at higher density. When offered three patches with trochus at different densities (5, 15 and 30 trochus.$patch^{-1}$) in large raceways, crabs did not identify the patches of high density, but instead moved frequently around all patches. After 48h, the proportion eaten was not significantly different among the three densities. These observations of crab behaviour suggest there was no response to increased prey densities due to the crabs' mobile foraging behaviour.

Field distributions of *Trochus*, *Turbo brunneus* (another herbivorous gastropod) and *Thais* (a predatory gastropod) were compared, and the frequency of recently dead undamaged shells was used as an indication of mortality by non-crushing predators (e.g. *Thais*). Distributions of *Trochus*, *Turbo* and *Thais* overlapped and all were often found in close proximity. The proportions of undamaged shells that were recently killed was 10% for *Trochus* and 28% for *Turbo*. The behaviour of *Trochus* and *Turbo* (potential prey) to the presence of *Thais* was observed in laboratory experiments. *Thais* elicited a response from both prey species, but these differed considerably: *Turbo* showed a conventional flight escape response, whereas *Trochus* did not change speed but instead released white mucus. Cultured and wild *Trochus* showed the same response when exposed to *Thais*. *Thais* showed a strong preference for *Turbo* as prey, but the capture of *Turbo* was inhibited in water containing mucus released by *Trochus*. The mucus response of *Trochus* provides protection from predation by *Thais*.

The difficulty associated with finding trochus on the reef and how this may affect estimates of survival was examined in two experiments, one at Orpheus Is., Australia and another at Moso Is., Vanuatu, using flagged trochus (with a bright tag and easier to see) and unflagged trochus. Recapture of flagged trochus 2-3 days after the release was significantly higher than for unflagged trochus in both experiments, supporting the hypothesis that a significant proportion of trochus are overlooked by the observer. Mean sighting probability of trochus at Orpheus Is. was 0.69 for an average size of 23 mm SW and 0.81 at Moso Is. for an average size of 30 mm SW.

A series of field experiments directly related to seeding were conducted. Two field techniques were used: releasing trochus freely onto the reef and tethering trochus to rods hammered into the reef substratum. Free releases lasted between a few days to a maximum of 4 months and tether experiments lasted a maximum of eight days.

In two experiments I examined the effect of seeding density on survival and growth, one experiment at Orpheus Is. and one at Moso Is. The effect of seeding density on trochus growth was also examined at Orpheus Is. Survival was very similar between low and high seeding densities 2-3 days after the release, in both experiments. The effect of seeding density on survival after a few days was not significant at any site, but at Moso Is., significantly more trochus were recaptured in the deeper zone. One to four months after the release, survival was again not significantly different between seeding densities but growth rates of trochus released at low density were significantly greater than those of trochus released at high density. Individual growth rates ranged between 1- 5 mm.month^{-1}. The detrimental effect on growth rate suggests that trochus should be released at low rather than at high density.

In five experiments at Orpheus Is. I examined the effect of trochus size and habitat on survival. Two main patterns emerged with high consistency in the results. First, survival of larger trochus was always greater; however, survival estimates varied among experiments. Small trochus (4-12 mm SW) and medium-large trochus were lost at a rate of 8-35% and 3-8% per day, respectively, over the first few days after the release. Second, trochus survival at different depth levels on the intertidal reef flat did not vary significantly. There was high variability among replicates, even five metres apart. Such variability is likely to be due to small scale differences in habitat characteristics which affect the distribution of predators and probability of trochus being detected. Analysis of trochus loss in a tether experiment showed that in 78% of cases where the number of trochus tethered to a rod decreased, only one trochus was lost at a time. This suggests that, after encountering and eating a trochus, predators did not remain in the area long enough to find another prey.

Mortality of cultured trochus immediately after release is very high but decreases with time, as is also the case for other species where cultured individuals are released for population enhancement. The results of this study emphasise the importance of increasing survival during that first period after release. The following procedures are likely to improve survival of released trochus:

1. It is better to release larger trochus. If possible, juveniles 20 mm SW or larger should be used in seeding reef environments.
2. It is better to spread trochus over a large section of the reef to reduce the risk of releasing them in an unfavourable area.
3. It is better to release trochus at low rather than high densities.
4. In monitoring survival through time, based on recapture rates, the probability of sighting a juvenile should be determined. This probability will depend on the size of trochus used and the characteristics of the habitat.
5. Great care should be given to the condition of the seed. Behaviour can be affected by disease or poor condition. Inappropriate behaviour (such as poor antipredator responses) could have important consequences on the susceptibility of trochus to attack by predators.

ACKNOWLEDGMENTS

I would like to thank John Lucas for guidance and support throughout this work and for his constructive criticism on the text.

Many volunteer field assistances joined me in my adventures on the reef flat at Orpheus Is. (and on the hill getting there). Their help is very much appreciated, most especially Melisendra Alvarez, Gilianne Brodie, Beth Brook, Emma Campbell, Jocey Davies, D. Gallagher, Mark Gotlieb, Esther Koh, Pilar Fernandez, Lek Manthrachitra, William Naviti, Marina Santurtun, Andy and Linda Sheldon and Amanda, Liz Wilson, Lisa Winston, Hugh Sweatman, Hideki Yukihira and Alex. Staff at Orpheus Is. Research Station helped to make the work easier and more pleasant, Virginia and Snow, Jeff and Bernice, Rob, Mike Huber and Kerry McGregor. William Naviti and Felix Nguyen from Vanuatu Fisheries Department, and their friends, helped with the work at Moso Is. in Vanuatu.

Many thanks to those who read chapters and gave useful comments, Julian Caley, Barry Goldman, Emma Gyuris, Uschi Kaly, Kathy Kavanagh, Vicky Hall, Lin Schwarzkopf, Warwick Nash and most especially to John Lucas and Hugh Sweatman.

Fred Wells kindly helped with the identification of some gastropods. Thanks to Garry Russ and Brett Molony for introducing the Fisat computer program, and to Dan Breen for advice on repeated measures analysis of variance. Hugh Sweatman answered endless statistical questions and, most especially, advised me on the use of randomising techniques and logistic regression analysis.

Many thanks to the Australian Centre for International Agricultural Research, who provided me with financial support for a large portion of this study. Other small grants were provided by the Department of Zoology at JCU, a Merit Research Grant from JCU and an Augmentative Research Grant from GBRMPA.

My loved family, parents, brother and sisters, cuñados and nephews, Pip and Jeanne, who have given all along the loving support that helps to achieve the set goals, whatever these are. They have been with me all the time.

And Hugh Sweatman, for whom thanks is not enough but is the only word I can think of. Thanks for a non-stop trochus discussion over these years, for providing advise on so many aspects of this work, for being patient and teaching me to be patient too, for being part of my life.

I wish to dedicate this thesis to "mis padres", Rosario and Bernardo Castell, and to "mi esposo" Hugh Sweatman.

TABLE OF CONTENTS

CHAPTER 1	General Introduction	1
1.1	History of seeding	3
1.2	Outline of this thesis	5
CHAPTER 2	**Population studies of juvenile *Trochus niloticus* and other gastropods on a reef flat on the North Queensland Coast, Australia.**	
2.1	Introduction	7
2.2	Study area	8
2.3	Methods	8
2.4	Results	12
2.4.1	Distribution and density of *Trochus niloticus*	12
2.4.2	Density and Distribution of other gastropods	20
2.4.3	Recruitment and growth of *Trochus*	24
2.5	Discussion	28
2.5.1	Distribution and density of *Trochus*	28
2.5.2	Density and distribution of other gastropods	30
2.5.3	Recruitment and growth of *Trochus*	31
2.5.4	Application to seeding	32
CHAPTER 3	**Laboratory studies of predation by portunid crabs on juvenile *Trochus niloticus*: prey size range, prey selection and vulnerability of prey**	
3.1	Introduction	34
3.2	Materials and Methods	35
3.2.1	Handling time	36
3.2.2	Size range of prey	37
3.2.3	Prey size choice	38
3.3	Results	39
3.3.1	Handling time and Profitability	39
3.3.2	Prey size range and vulnerability	43
3.3.3	Prey size choice	43
3.4	Discussion	50
3.4.1	Prey size range and prey size selection	50
3.4.2	Vulnerability function and application to seeding	53
CHAPTER 4	**Predation response of portunid crabs to different densities of juvenile *Trochus niloticus***	
4.1	Introduction	55
4.2	Materials and Methods	56
4.2.1	Response to prey density in patches	57
4.2.2	Effect of prey density on predation rate	58
4.3	Results	59
4.3.1	Patch foraging	59
4.3.2	Effect of density on predation rate in container experiments	65
4.4	Discussion	71

CHAPTER 5 **Predator - prey interactions among *Trochus niloticus*, *Turbo brunneus* and *Thais tuberosa***

5.1 Introduction 75
5.2 Methods 76
5.2.1 The Prey 76
5.2.2 Distribution 77
5.2.3 Prey responses 77
5.2.3.1 Laboratory experiments 77
5.2.3.2 Field experiments 78
5.2.4 Prey choice 78
5.3 Results 79
5.3.1 Distribution 79
5.3.2 Prey response 82
5.3.3 Prey choice 87
5.4 Discussion 91
5.5 Comparison of cultured vs. wild *Trochus* 94

CHAPTER 6 **Detectability of cryptic juvenile *Trochus* in stock enhancement experiments**

6.1 Introduction 95
6.2 Methods 95
6.2.1 Study sites 95
6.2.2 Experiment 1 (Orpheus Is.) 96
6.2.3 Experiment 2 (Moso Is.) 96
6.2.4 Data analysis 96
6.3 Results 96
6.3.1 Experiment 1 (Orpheus Is.) 96
6.3.2 Experiment 2 (Moso Is.) 101
6.3.3 Estimates of survival (Exps. 1 and 2) 101
6.4 Discussion 101

CHAPTER 7 **Effect of seeding density on survival and growth of juvenile *Trochus***

7.1 Introduction 110
7.2 Methods 111
7.2.1 Experiment 1, Orpheus Is. 111
7.2.2 Experiment 2, Moso Is. 113
7.2.3 Data analysis 113
7.3 Results 114
7.3.1 Experiment 1, Orpheus Is. 114
7.3.2 Experiment 2, Moso Is. 119
7.4 Discussion 124
7.4.1 Sources of juvenile loss 124
7.4.2 Short-term vs. long-term effects of initial seeding density ... 126
7.4.2.1 Survival 126
7.4.2.2 Growth rate 127
7.5 Application to seeding 128

CHAPTER 8 **Effect of juvenile size and location of release on survival of juvenile *Trochus* in field releases**

8.1 Introduction 129

8.2 Study site 130
8.3 General methods 130
8.3.1 Release experiments 130
8.3.2 Tether experiments 133
8.4 Results 134
8.4.1 Release experiments 134
8.4.2 Tether experiments 140
8.5 Discussion 155
8.5.1 Trochus size 155
8.5.2 Habitat 159
8.5.3 Patterns of mortality 161

CHAPTER 9 **General Discussion**
9.1 Limitations and assumptions 162
9.1.1 Highest mortality shortly after release 162
9.1.2 The logistics of working with juvenile Trochus in their reef environment 163
9.2 Applications of the results 164
9.2.1 Ways of increasing trochus survival 164
9.2.2 Mortality rates and feasibility of seeding 167

References 173

Appendix 1 184