TROCHUS
and other marine molluscs
information bulletin

Editors' note

A few months ago, when we became editors of the *SPC Trochus Information Bulletin*, we knew we would be exchanging ideas and experiences with dedicated people and acquiring a greater understanding of trochus and other fascinating molluscs. We are now proud to offer you this "lucky" issue #13. You will find that it further reflects the new wider scope of the Bulletin, extending to non-trochid marine molluscs.

On the menu for this issue are two surveys from the Cook Islands contributed by Charlotte Chambers (Institute of Geography, University of Edinburgh): one on trochus resources (*Trochus niloticus*) and the other on giant clams (*Tridacna maxima*). You will also find a report from Do Huu Hoang and collaborators (Institute of Oceanography, Vietnam) outlining the first results of a project on trochus grow-out and stock enhancement in Vietnam. We also include a short note on the behaviour and development of a colourful opisthobranch (*Hydatina physis*) from the Solomon Islands. Finally, we have compiled an extensive list of recent abstracts from books, articles and conferences that pertain to many species and topics of interest to marine malacologists worldwide.

In concluding this introduction, we cordially invite you to submit your contributions for issue #14. We hope to receive diversified submissions from collaborators working on trochus or any other species of gastropods and bivalves. While the focus remains on Indo-Pacific species, contributions from other regions are appreciated as well. As you know, the Bulletin is open to a number of subject matters, including biology (e.g. distribution, spawning, development, feeding, diseases, etc.), resource management (e.g. fishery, farming, aquaculture, aquarium industry, etc.) and conservation issues. We welcome both complete articles and short notes on these topics, not to mention pertinent informal bits (announcements, news, book excerpts or reviews, and summaries of theses, published work and conferences). Please feel free to spread the word, and to contact us if you have new ideas or want to discuss the content of your prospective contribution.

We remind you that the *SPC Trochus Information Bulletin* is published in English and French, distributed worldwide and indexed in databases such as ASFA. It is also available on the Internet through the SPC webpages, where you will also find our complete instructions for authors (http://www.spc.int/coastfish/News/SIG-instructions.pdf).

Molluscs are among the most studied marine invertebrates on the globe; we therefore look forward to new reports and pertinent information from all of you who share this wonderful passion. Meanwhile, please enjoy issue #13 of this Bulletin!

Jean-François Hamel and Annie Mercier

Trochus (*Trochus niloticus*) size and abundance in Tongareva Lagoon, Cook Islands

Charlotte N.L. Chambers

Introduction

Trochus (*Trochus niloticus*) were first introduced to the Cook Islands in 1957 from Fiji. Once the original population of 280 shells was well established in Aitutaki, trochus were introduced to the rest of the Cook Islands in the 1980s. The main purpose of the introduction was to develop commercially harvestable stocks to assist local economies. Four hundred and forty trochus were introduced to Tongareva (also known as Penrhyn) over 20 years ago in 1985 from the Aitutaki population (Sims 1988). Introduced populations usually reach commercially exploitable levels within 20 to 25 years, therefore, the trochus population on Tongareva should nearly be ready for harvest (Bertram 1998).

Trochus tend to be distributed according to age, with juveniles found in shallow areas among coral rubble and adults found in increasing densities towards the reef edge. The optimum depth for trochus is up to 10 m, although they can be found as deep as 25 m (Bertram 1998). Trochus feed by grazing coral and rocks for microscopic algae and diatoms. They reach reproductive maturity at around two years of age when the animal has a basal diameter of approximately 6 cm. The life span of trochus is around 15 years, when they reach a basal diameter of around 15 cm. According to Sims (1988), trochus spawn approximately three to five times a year. Fertilisation occurs externally with a short larval phase of three to five days. This short larval phase does not allow for large natural dispersal, hence trochus populations are considered isolated and are not likely to spread to other reefs (Bertram 1998).

A 1996 survey conducted in Tongareva by the Cook Islands Ministry of Marine Resources (MMR) found that trochus were present in the western section of Tongareva Lagoon with the highest densities found at two sites: Patukiri and Seniseni (Ponia et al. 1997). The survey detailed in this report was designed to re-assess the density of trochus in Tongareva Lagoon, 10 years after the last survey and 20 years after the original introduction.

The specific aims of the survey were to:

- assess the size distribution of trochus,
- assess trochus abundance and density in the western section of the lagoon, and
- estimate the number of trochus that could be sustainably harvested from the surveyed area of the lagoon.

Methodology

The survey took place from 3–11 May 2006 with a follow-up survey in Patukiri on 31 May 2006, in conjunction with a survey of *pasua* (*Tridacna maxima*) populations. Fieldwork was conducted by the author, Mataora Marsters and Taimana Manata from the Tongareva Marine Research Centre (TMRC), with additional assistance from Tomas Samuela Jr and Tuku Marsters. Surveying was concentrated in the western section of the lagoon (Fig. 1) as this was where the highest numbers of trochus were discovered in the previous survey. However, any trochus encountered in other sections of the lagoon during the course of the *pasua* survey were also to be recorded although none were found.

From preliminary observations and also based on previous surveys of trochus numbers, it was observed that trochus were distributed with increasing density towards the edge of the inner lagoon reef (*kauniho*). Transect lines were accordingly placed at the edge of the *kauniho* extending towards the shoreline. The survey was conducted using a 50-m transect line laid parallel to the edge of the *kauniho* with five transect lines running perpendicular at 10-m intervals. All trochus found within 5 m on both side of the transect line were counted and all were measured except those surveyed at TMRC, where approximately every second trochus was measured (i.e. 39% of the population) and Patukiri North where 85% of the population were measured.

The size distribution of trochus was evaluated by recording the basal diameter of trochus using callipers. The census of trochus abundance in the
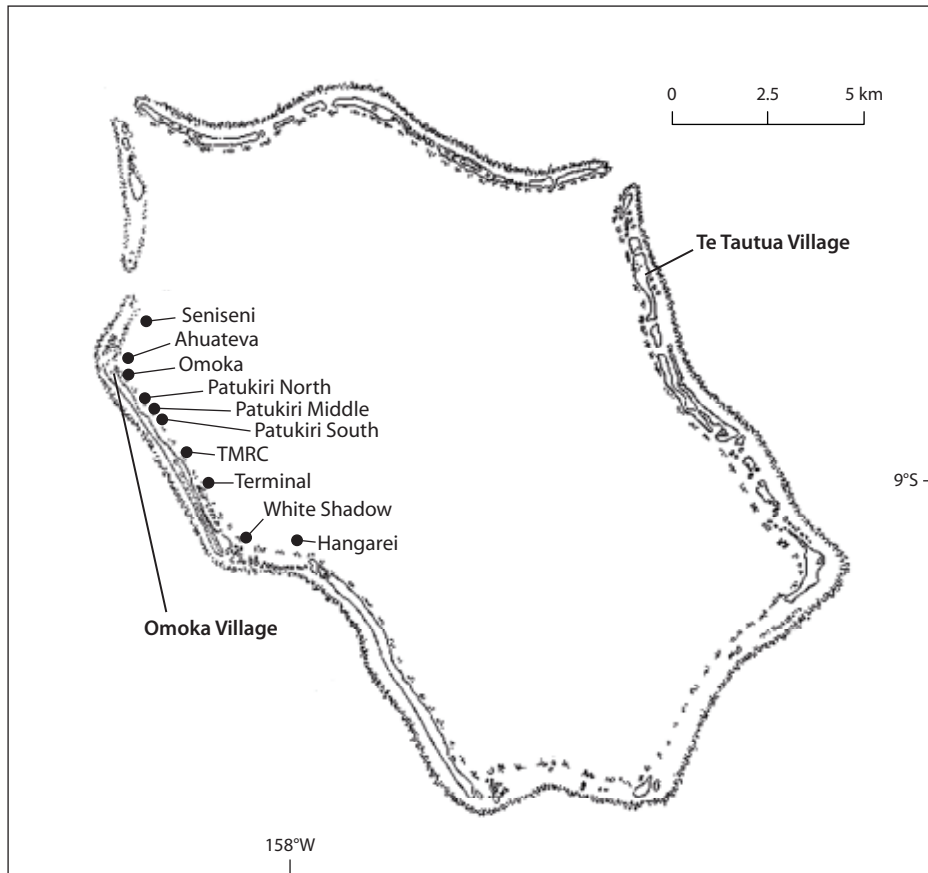
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Figure 1. Survey sites in Tongareva Lagoon showing the two main villages
Omoka and Te Tautua.

lagoon was calculated by counting the number of trochus at each site; density was calculated as the total number of individuals divided by the area sampled, which at each site was 2500 m². The calculation for the amount of trochus available for sustainable harvest was based around 30% of the population in the 8–12 cm size range as per harvest regulations established in Aitutaki. Ten sites were surveyed (Fig. 1).

Results

Size distribution

The mean basal diameter of the trochus shells sampled was 9.17 cm (n = 451), which was an increase of 0.77 cm from the previous survey conducted 10 years ago by Ponia et al. (1997). Of the 433 trochus measured, 406 individuals or 93.76% were of legal size, that is, above the 8 cm minimum and under the 12 cm maximum (Fig. 2). The minimum size limit is designed to allow young trochus the opportunity to spawn before reaching a harvestable size, while the maximum size limit is set to retain large individuals as a breeding stock for future trochus populations

and also to accommodate the fact that as trochus age, the value of the shell decreases due to the presence of organisms on the shell surface such as algae and tubeworms (Bertram 1998). Three of the trochus measured were found to exceed 12 cm compared to just one in the previous surveys, whereas 24 were under the 8 cm minimum size bracket. The largest trochus, measuring 15.4 cm, was found at the White Shadow site and the smallest one, measuring 2.5 cm, at TMRC. The largest sized trochus on average were found at the Patukiri North site (n = 13) with a mean of 10.43 cm. The smallest sized trochus on average were found at the Terminal site (n = 4) with a mean of 4.7 cm.

Population abundance and density

The highest numbers of trochus were found at Omoka and TMRC sites (Table 1). The corresponding densities were 0.075 ind m⁻² and 0.065 ind m⁻², respectively. Low numbers were recorded at Patukiri North and at sites in the southwestern end of the lagoon (Terminal, White Shadow and Hangarei), resulting in a combined average density for the entire population of 0.022 ind m⁻². The low numbers
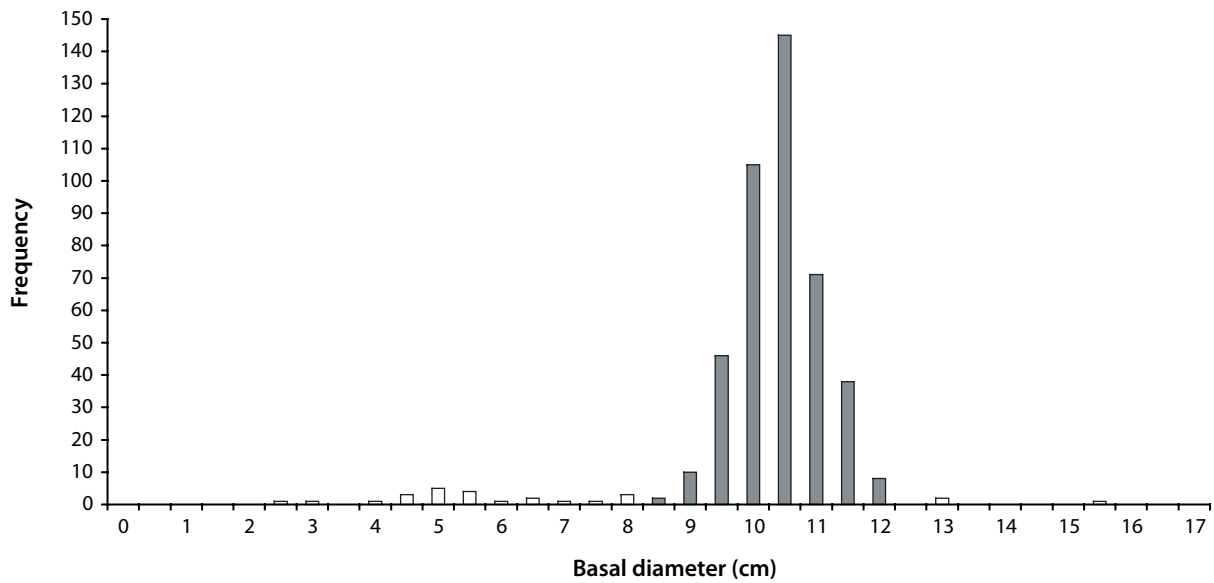
Figure 2. Trochus population size structure indicating shells within the legal size range in grey.

recorded at the Patukiri North site are unusual given the high numbers recorded at neighbouring Omoka and the increasing numbers discovered as the survey moved southward. This discrepancy prompted a resurvey of the area, which found numbers increasing as the survey moved southward.

No other trochus were recorded at any other sites visited in the lagoon during the course of the *pasua* survey although this survey largely focussed on coral heads throughout the lagoon instead of *kauniho*. The one survey conducted in possible trochus habitat on the eastern side of the lagoon (site Matinono) did not find any trochus. A further survey on the eastern side of the lagoon, near Te Tautua, is recommended for confirmation of trochus absence in this region.

Harvest capacity

As discussed, of the trochus measured, 406 individuals (93.76%) were in the legal size range.

Extrapolating this to the total number of trochus counted (554) suggests that 519 shells would be in the legal size range of the area surveyed. In accordance with the sustainable limits for trochus harvesting set on Aitutaki, which allows 30% of the population in the legal size range to be taken, the number of individuals available for harvest is 121 of the total shells measured, or 155 individuals when extrapolated according to total number of shells counted. It is important to note that these calculations apply only to the area surveyed (25,000 m²). In order to attain a better estimate of the total number of trochus potentially harvestable from Tongareva Lagoon, these calculations need to be extended according to the area of suitable trochus habitat in Tongareva Lagoon.

The weight of this potential harvest could then be calculated according to the following relationship between basal diameter (L) and weight (W) where $W = (3.4 \times 10^{-4}) L^{2.943}$ as used by Ponia et al. (1997).

Table 1. Abundance and density of trochus at different sites surveyed

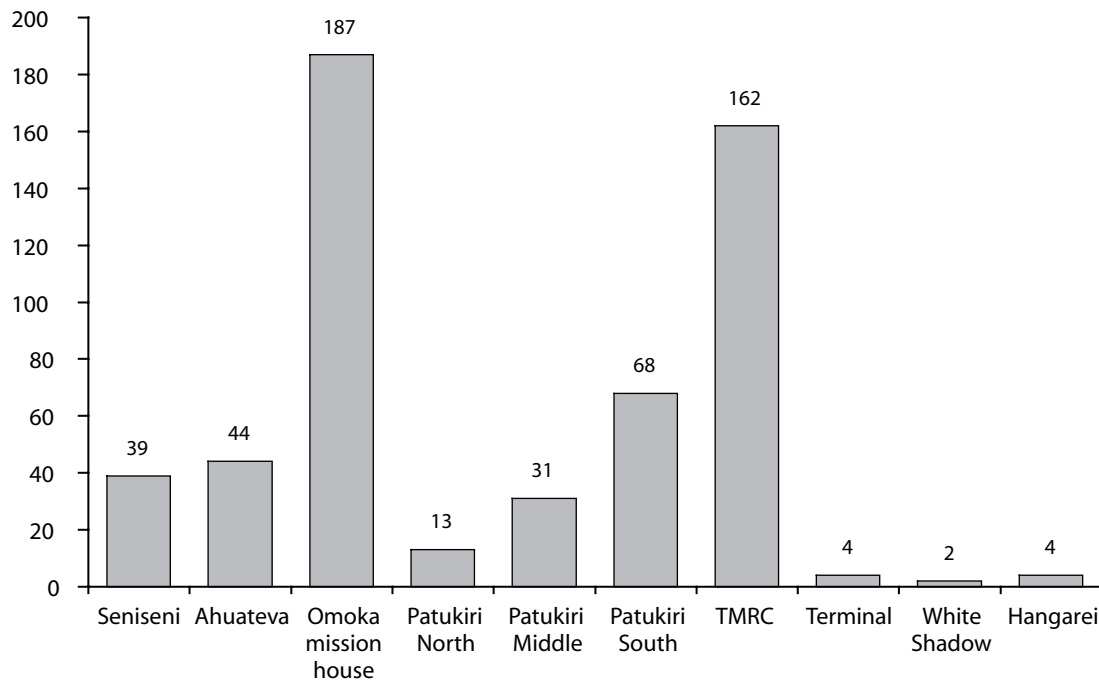| Site name | Seniseni | | Omoka | | P middle | | TMRC | | White Shadow | |
		Ahuatera		P North		P South		Terminal		Hangarei
Count (n)	39	44	187	13	31	68	162	4	2	4
Density (ind m⁻²)	0.016	0.018	0.075	0.005	0.012	0.027	0.065	0.002	0.001	0.002

Figure 3. Number of trochus found in each site surveyed.

Conclusions and recommendations

Bertram's report in 1998 estimated the trochus yield on Tongareva to be around 110 t, to be achieved within 10–15 years (Bertram 1998). Once the results from the present survey are extrapolated according to the total area of suitable trochus habitat, that is, the coastline from Seniseni to Hangarei, this estimate will need to be updated. The majority of trochus measured in this survey are of a harvestable size so it appears that a harvest on Tongareva would be a timely event and one beneficial for the local economy. It is recommended that the coastline around Te Tautua be surveyed to confirm the absence of trochus in this area of the lagoon. Based on size distribution patterns, it is recommended that the existing size limits of 8 to 12 cm be retained although there is scope to extend the harvest quota to 40% to make the harvest a financially viable exercise for the Tongarevan community.

References

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Sims N.A. 1988. Trochus resources profile report for Cook Islands. Rarotonga, Cook Islands Ministry of Marine Resources. 12 p.

Appendix 1. Tongareva trochus survey

10 sites:	Totals	Seniseni	Ahuateva	Omoka	Patukiri North	Patukiri Middle	Patukiri South	TMRC	Terminal	White Shadow	Hangarei
Area surveyed (m^2)	25,000	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
No of shells found	554	39	44	187	13	31	68	162	4	2	4
Density (shells m^{-2})	0.022	0.016	0.018	0.075	0.005	0.012	0.027	0.065	0.002	0.001	0.002
No of shells measured	433	39	44	169	11	31	68	61	4	2	4
% of shells measured	78.16	100.00	100.00	90.37	84.62	100.00	100.00	37.65	100.00	100.00	100.00
Av. shell size (cm)	9.17	9.97	9.80	9.87	10.43	10.32	10.09	6.72	4.70	9.85	9.98
Max. size (cm)	15.40	11.40	11.00	11.00	11.20	12.50	11.50	10.70	5.40	15.40	11.00
Min. size (cm)	2.40	9.20	4.30	5.70	8.40	9.00	5.00	2.40	4.00	4.30	7.80
No > 120 mm	3	0	0	1	0	1	0	0	0	1	0
No ≤ 80 mm	24	0	2	2	0	0	1	13	4	1	1
Total no of legal size measured shells	406	39	42	166	11	30	67	48	0	0	3
% legal	93.76	100.00	95.45	98.22	100.00	96.77	98.52	78.68	0	0	75.00
Extrapolated total number of legal size	519	39	42	184	13	30	67	127	0	0	3

Pasua (*Tridacna maxima*) size and abundance in Tongareva Lagoon, Cook Islands

Charlotte N.L. Chambers[1]

Introduction

Pasua (*Tridacna maxima*), also known as *pa'ua*, are one of two species of giant clams native to the Cook Islands. *Pasua* are a culturally significant food item throughout the Cook Islands, and in the Northern Cooks remain a staple food source. *Pasua* are rare in the southern Cook Islands as a consequence of previous overharvesting, but increasing numbers of *pasua* from the northern Cook Islands, especially Tongareva, are available for sale in Rarotonga. In response to declining numbers in the southern Cook Islands, a giant clam hatchery was established on Aitutaki in 1990 by the Cook Islands Ministry of Marine Resources (MMR) to help reintroduce clams to the lagoon.

Pasua, as other tridacnid species, are classed as protandrous functional hermaphrodites, meaning they mature first as males, developing later to function as both male and female. According to Lewis (1987), *T. maxima* begin to reach sexual maturity as males at approximately 6 cm; 50% of both males and females are sexually mature at 10 cm; and 100% are sexually mature at 14 cm and larger. *T. maxima* are also very slow growing and according to Lewis' study in Aitutaki, they take five years to reach 10 cm in length, 10 years to reach 15 cm and 15 to 20 years to reach 20 cm and above. As a consequence, *T. maxima* are thought to be able to live for several decades. According to Heslinga et al. (undated), very large clams (that is, above 15 cm) are important for future reproduction as they produce the largest numbers of eggs during spawning. While growth rates and longevity may vary slightly for *T. maxima* present in Tongareva Lagoon, these estimates are used as a baseline for the purposes of this study.

T. maxima, as other tridacnid species, usually grow on firm substrate such as coral or rock (Fig. 1). Once settled after spawning, the clam attaches itself to the bottom with byssal threads. These threads are designed to keep the clam upright and prevent displacement by currents or marine predators. In their juvenile state, *T. maxima* are vulnerable to predation, although after reaching 10 cm, the chances of mortality from non-human causes are significantly lower due to the thick protective shell and firm embedment in the surrounding substrata (e.g. rocks or coral). Known non-human predators of *T. maxima* include large triggerfish (*Pseudobalistes flavimarginatus*), octopi, eagle rays (*Aetobatis narinari*) and pufferfish (*Tetradon stellatus*). At the juvenile stage, in addition to the dangers posed by crushing predators, *T. maxima* are also vulnerable to the snail species *Cymatium muricinum*, which attacks the clams through the byssal opening (the root) (Heslinga et al. 1990).

All tridacnid species are susceptible to over-exploitation due to the ease with which they can be collected (they do not move and are easy to spot from the surface), the slow rate at which they mature,

Figure 1. *Pasua* commonly grow on firm substrates such as coral.
Photo: C. Chambers, 2006.

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and the sporadic timing of their reproduction (MMR undated). In addition to these biological characteristics, pressure is being placed on *pasua* populations on the island of Tongareva, where large-scale *pasua* harvests are increasing in frequency, in order to meet demand for this highly sought-after food source. Due to concerns expressed by the Island Council on Tongareva, it was decided to undertake a survey of *pasua* numbers in Tongareva Lagoon so as to assist with future decisions regarding the need for conservation measures.

The specific aims of the survey were to assess the size distribution, abundance and density of *pasua* in Tongareva Lagoon.

In addition, this survey aimed to provide baseline information for the Island Council regarding the establishment of specific size limits, the possible need for a *rahui* (harvest closure), and the ideal location of such a *rahui* if required.

Methodology

The survey took place over 14 days from 3–17 May 2006 with a follow-up survey at sites Te Vo, Tepetepe and between Ahuamiria and Atutahi on 24 July 2006. Fieldwork was conducted by the author, Mataora Marsters and Taimana Manata from the Tongareva Marine Research Centre (TMRC) with additional assistance from Tomas Samuela Jr., Tuku Marsters, Martin Chambers and Baar Tapu. Site selection was designed in an attempt to survey a wide cross section of the lagoon environment, for example *toka* (distinct coral heads), *tuarai* (small scattered coral heads close to shore) and *kauniho* (reef edges). Sites were stratified according to the section of the lagoon (e.g. far southern section) and were selected by travelling in a boat within these sections in a relatively straight line (e.g. parallel to the shore) for a set period of time (e.g. 10 minutes) until suitable habitat was encountered. From preliminary observations and based on existing biological information concerning *pasua* (Lewis 1987), suitable habitat was defined as *toka* and *tuarai* down to a depth of 10 metres, and *kauniho*, which weren't predominately sandy.

The survey area was delineated by four 50-m ropes, which were knotted to form a square. This was then placed randomly over the survey site although in the case of *kauniho*, the lines were placed at the edge of the *kauniho* extending towards the shoreline. Five transect lines were then placed within the square at 10-m intervals. All *pasua* found within 5 m on each side of the transect line were counted and a

proportion of the total population measured. In cases where low numbers of *pasua* were present, every second *pasua* was measured but in situations where large numbers were found, measurements varied from every tenth to every one-hundreth *pasua*.

The size distribution of *pasua* was evaluated by recording the length, measured in centimetres, along the shell opening (lip) using callipers (Fig. 2). The census of *pasua* abundance in the lagoon was calculated by counting the number of *pasua* within each survey area; density was calculated as the total number of individuals divided by the area sampled which at each site was 2500 m^2. A total of 27 sites in the lagoon were surveyed (Fig. 3).

Figure 2. Mataora Marsters demonstrates the use of callipers on the first day of the survey.
Photo: C. Chambers, 2006.

Results

Size distribution

The average length of the *pasua* sampled was 10.59 cm (n = 1332 shells), which equates to an average age of five years. As seen in Figure 4, of the 1332 *pasua* measured, 16.2% were less than 5 cm, representing the proportion of the population that were sexually immature (white bars). Only 21.5% were fully sexually mature, that is, above 14 cm (black bars). The largest sized *pasua,* found at the Te Vo *kauniho,* was measured at 20.2 cm; smallest sized *pasua* of 1 cm were found at several sites. The largest *pasua* on average were found at the Koroatini site (total population 29; 10 shells measured) with an average length of 13.35 cm. The smallest *pasua* on average were found at the Motu Unga *kauniho* (total population 89; 12 shells measured) with an average length of 7.64 cm.
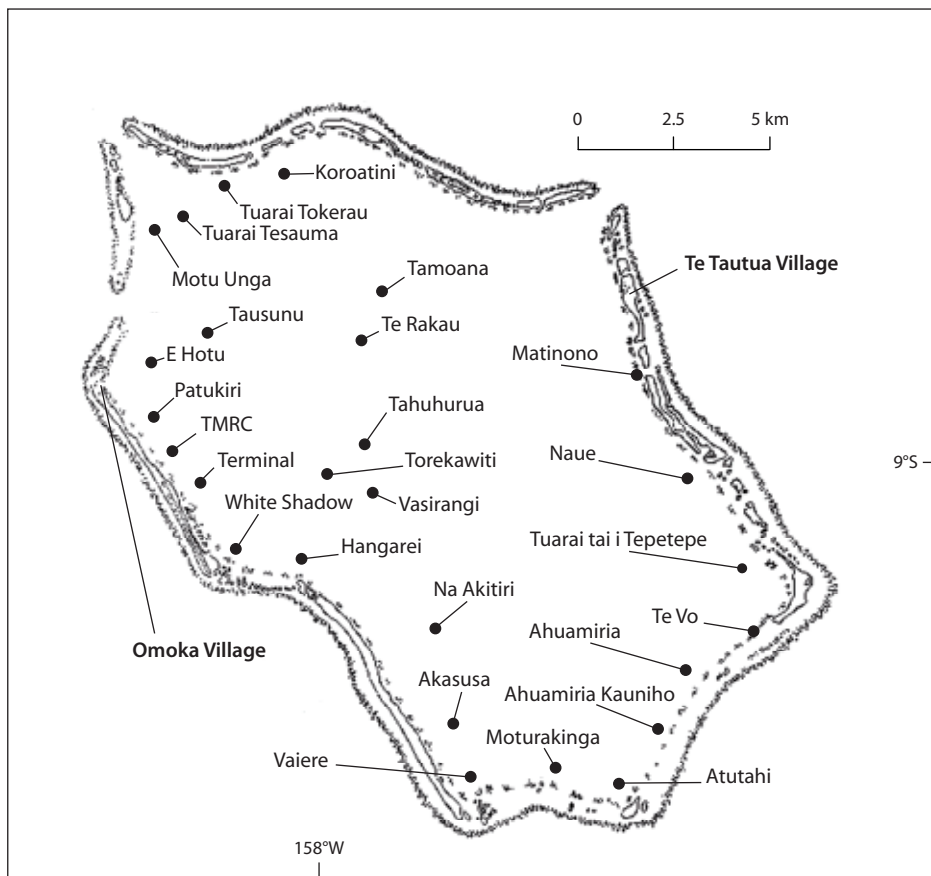
Figure 3. Approximate location of the sites surveyed in Tongareva Lagoon
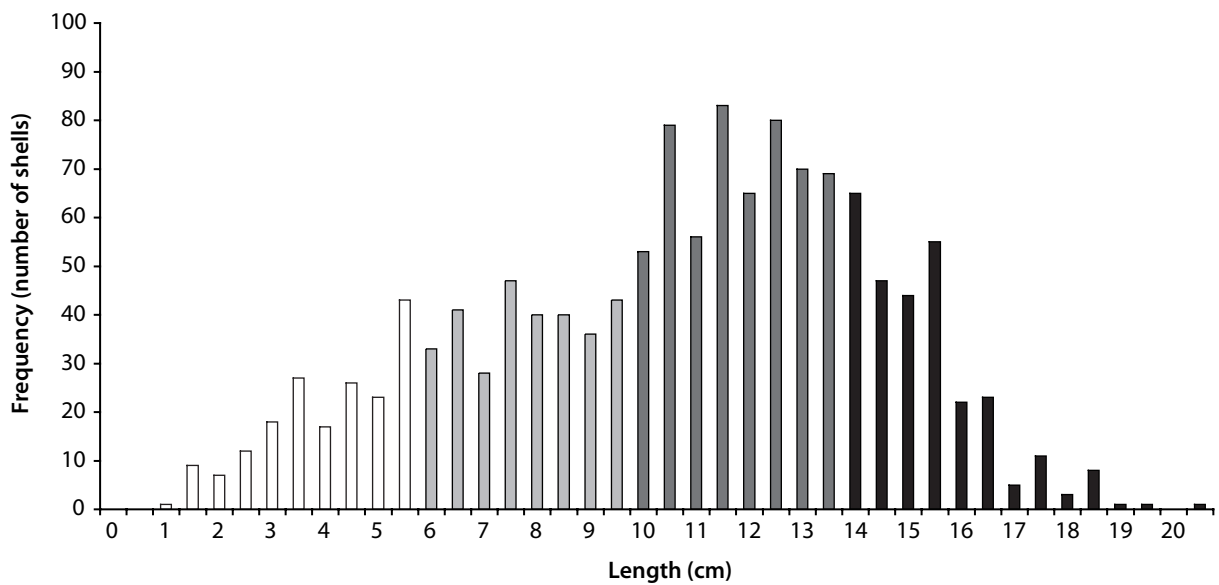and the villages of Te Tautua and Omoka

Figure 4. Combined lengths of the Tongareva *pasua* population sampled in the study.
The population roughly fits a normal distribution curve with the majority of the *pasua* 10.5 cm, 11.5 cm and 12.5 cm
in length. The coloured bars differentiate the population according to sexual maturity, with white bars indicating
the proportion of the population deemed to be sexually immature and the black bars, fully sexually mature.

Population abundance and density

The total number of *pasua* counted during the survey was 28,066 shells. This number was concentrated in the southern section of the lagoon with the highest numbers recorded at the *tuarai* off Moturakinga with high numbers also recorded at the *tuarai* off Ahuamiria and the *kauniho* at Te Vo (see Fig. 5). The corresponding densities for these sites were 2.69 ind m^{-2}, 1.6 ind m^{-2} and 1.56 ind m^{-2}, respectively. The lowest numbers of *pasua* recorded were at the *toka* Te Rakau and Tamoana (n = 22 or 0.01 ind m^{-2}) with similarly low densities recorded at Koroatini and the *tuarai* off Tokerau (for full details see Appendix 1). In general, it appeared that numbers increased the farther south and the farther away the sites were to the villages of Omoka and Te Tautua. This trend is discussed in more detail in the recommendations section. A number of sites, despite being surrounded by high *pasua* densities, were found to have relatively low numbers of *pasua*. For example, the low numbers recorded at the Akasusa *tuarai* and Vaiere *kauniho* are unusual given the high numbers recorded at neighbouring sites Moturakinga and Atutahi. Similarly, on the southeastern side of the lagoon, low numbers were recorded at the *tuarai* off Tepetepe which is close to the high populations of Te Vo and Ahuamiria (see Fig. 3).

The overall density of *pasua* was 0.42 ind m^{-2} for the overall area surveyed of 67,500 m^2. Tongareva Lagoon is extremely large and while not all of it provides suitable *pasua* habitat, the densities suggested in this study need to be extrapolated according to the total area of suitable habitat (all *toka, tuarai* and *kauniho*) present in the lagoon. Ideally, this would be done in a stratified manner so as to take into account areas of the lagoon containing high numbers of *pasua* (e.g. the southwestern section), and the areas that do not (e.g. the northeastern section).

Discussion and recommendations

As mentioned in the introduction, *pasua* are both slow growing and slow to reach full sexual maturity. *Pasua* take five years to reach 10 cm and once they reach 10 cm, it takes them a further five years to reach 15 cm, a size at which they are deemed fully sexually mature. Therefore, it is recommended that the idea of specific

Figure 5. Total number of *pasua* counted during the survey.
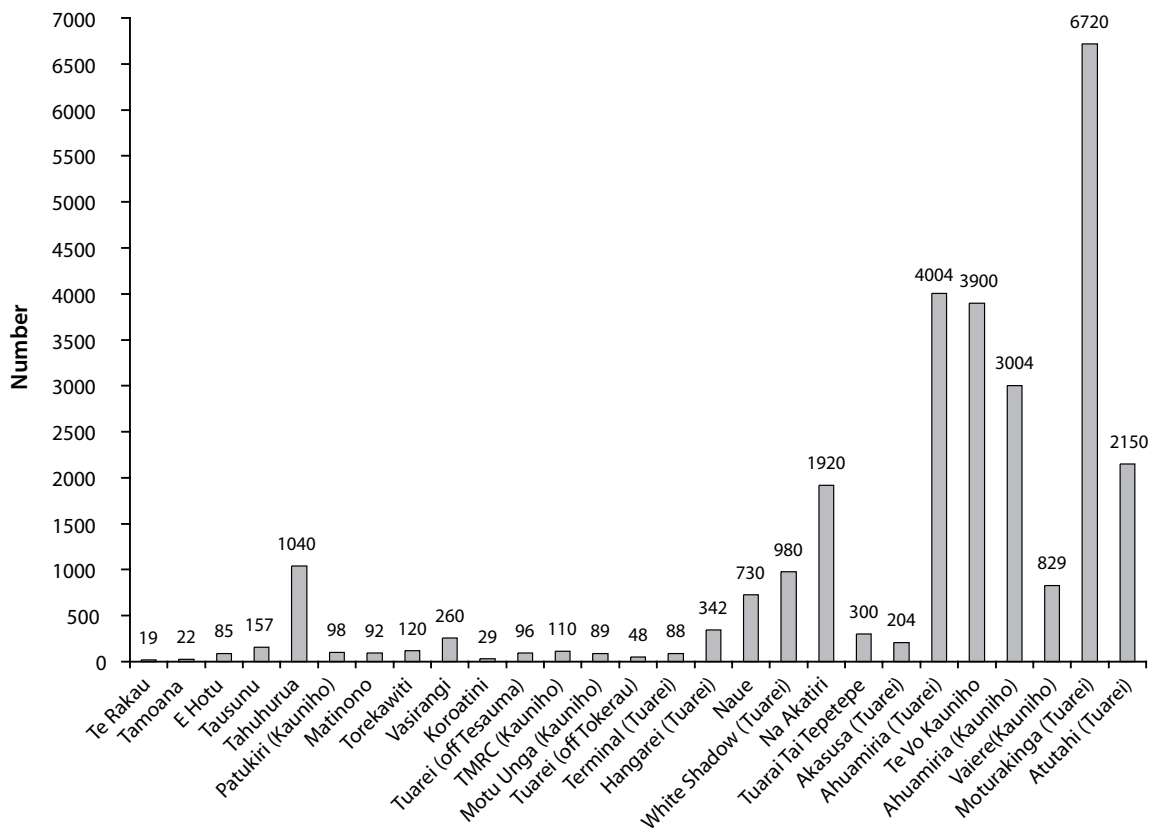As this graph demonstrates, the number of *pasua* increases dramatically the farther south and the farther away from the villages of Omoka and Te Tautua the study surveyed with numbers peaking at the *tuarai* off Moturakinga. The exceptions to this pattern are the *tuarai* off Tepetepe and Akasusa where numbers were well below the overall average of 790 shells per site.

size restrictions be considered for future *pasua* harvests. Ideal size restrictions would allow young *pasua* the opportunity to spawn before reaching a harvestable size and also retain a proportion of the sexually mature population as a breeding stock for future populations. According to the figures recorded in this study, a minimum size limit of 10 cm and a maximum size limit of 16 cm would make 58% of the surveyed population, or 15,225 individuals, available for harvest while leaving a good proportion of the sexually immature and mature population for future reproduction.

The distribution patterns outlined in Figure 5 could be interpreted as suggesting harvest pressure on *pasua*. The conditions in the southern section of the lagoon provide ideal *pasua* growing conditions with numerous *tuarai* and small coral heads, which are not subject to strong currents found near the entrance passages to Tongareva Lagoon (Fig. 6). Indeed, it is common knowledge among Tongareva residents that the southern section of the lagoon is a good *pasua* harvesting ground. Interviews conducted with residents during the course of the author's visit to Tongareva suggest that *pasua* used to be present in large numbers close to the villages of Omoka and Te Tautua but in recent years people have needed to travel farther away in order to harvest large numbers of decent sized *pasua*. Many people interviewed also expressed unease with the increasing rate of large-scale harvests of *pasua* motivated by the good money to be made by selling *pasua* in Rarotonga. It was often suggested that a *rahui* may be needed to protect the Tongareva *pasua* population from this harvest pressure. Concern was expressed, however, as to where such a *rahui* would be located, and whether it would allow people the ability to continue to harvest *pasua* for home consumption (Chambers 2006). Given the results from this survey, it is recommended that certain *toka* and specific areas of the lagoon where low numbers of *pasua* are to be found (e.g. Vaiere, Akasusa, Tepetepe and Hangarei) are considered *rahui* for large-scale harvests but that these areas are open to people wishing to harvest *pasua* for home consumption. Such a *rahui* on large-scale harvests should be maintained for at least five years to allow young pasua to grow to 10 cm where at least 50% of both males and females will be sexually mature, while also allowing existing mature *pasua* time to spawn.

In summary, it is recommended that the following measures be considered by the Tongareva Island Council in order to protect *pasua* populations from overharvesting:

1. impose a minimum size limit of 10 cm and a maximum size limit of 16 cm (or similar) for all *pasua* harvested; and, at minimum,

2. declare a *rahui* for the areas of Vaiere, Akasusa, Tepetepe, and Hangarei for a period of five or more years.

Figure 6. Vaiere is characteristic of the southern section of Tongareva Lagoon where there are numerous small coral heads close to shore. *Photo: C. Chambers, 2006.*

Acknowledgements

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Chambers C.N.L. 2006. Relational knowledge and marine conservation: The case of the pasua rahui, Tongareva, Cook Islands. The 2nd International Small Island Cultures Conference 2006, Museum Theatre, Norfolk Island Museum, 9–13 February 2006, Maquarie University Press.

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Appendix 1. Tongareva *pasua* survey summary

Sites (27)	Area surveyed (m²)	Av. shell size (cm)	Total popul.	Shells measured	% of shells measured	Density (shells m⁻²)	Max. size (cm)	Min. size (cm)
Overall	67500	10.59	28066	1332	4.75	0.42	20.2	1
Akasusa (*tuarei*)	2500	10.02	204	69	33.82	0.08	18.1	1.4
Vaiere (*kauniho*)	2500	8.06	829	102	12.3	0.33	16	1
Moturakinga (*tuarei*)	2500	8.68	6720	152	2.26	2.69	15.3	1.2
Atutahi (*tuarei*)	2500	9.87	2150	86	4	0.86	18	1
Ahuamiria (*tuarei*)	2500	9.41	4004	137	3.42	1.6	18	1
Patukiri (*kauniho*)	2500	10.21	98	19	19.39	0.04	14.2	5.8
Terminal (*tuarei*)	2500	9.56	88	22	25	0.04	13.6	4.9
Hangarei (*tuarei*)	2500	9.75	342	15	4.39	0.14	15	3.8
TMRC (*kauniho*)	2500	9.7	110	32	29.09	0.04	14.1	2.5
White Shadow (*tuarei*)	2500	11.29	980	79	8.06	0.39	19	3.3
Na Akatiri	2500	12.6	1920	81	4.22	0.77	18.4	3.6
Matinono	2500	12.75	92	28	30.43	0.04	18.2	2.9
Naue	2500	10.49	730	75	10.27	0.29	17.5	1.3
Tamoana	2500	11.59	22	12	54.55	0.01	15.3	4.4
Te Rakau	2500	11.64	19	11	57.89	0.01	14.2	5.7
Koroatini	2500	13.35	29	10	34.48	0.01	18.6	3
Tuarei (off Tokerau)	2500	7.89	48	10	20.83	0.02	12.5	3.4
Tuarei (off Tesauma)	2500	11.74	96	16	16.67	0.04	16.3	8.5
Motu Unga (*kauniho*)	2500	7.64	89	12	13.48	0.04	12	4.3
Tausunu	2500	11.92	157	17	10.83	0.06	14	9
E Hotu	2500	12.2	85	7	8.24	0.03	14.8	10.2
Torekawiti	2500	10.51	750	39	5.2	0.3	17	3.5
Tahuhurua	2500	10.75	1040	45	4.33	0.42	16.7	2.7
Vasirangi	2500	10.37	260	39	15	0.1	15.2	5.1
Te Vo Kauniho	2500	11.72	3900	84	2.15	1.56	20.2	3
Tuarai Tai Tepetepe	2500	12.57	300	52	17.33	0.12	18	3.3
Kauniho I roto pu o ahuamiria raua ma atutahi	2500	9.71	3004	81	2.7	1.2	16.3	2

Experiments on using hatchery-reared *Trochus niloticus* juveniles for stock enhancement in Vietnam

Do Huu Hoang[1]*, Vo Si Tuan[1], Nguyen Xuan Hoa[1], Huynh Minh Sang[1], Hoang Duc Lu[1] and Hua Thai Tuyen[1]

Abstract

The topshell (*Trochus niloticus* Linnaeus, 1767) is a commercially exploited mollusc that is commonly found on Indo-Pacific coral reefs. One effective method of replenishing natural populations of trochus is artificial breeding and the release of larvae and juveniles into the wild. Artificial breeding has been successful at the Institute of Oceanography, Nha Trang, in Vietnam. Artificially reared trochus seeds were used for restocking, based on community management at Chao Reef (12°22′39″S; 109°18′18″E). Results on trochus growth rates at different culture densities in cages showed that appropriate densities were: 100 ind m^{-2} for specimens measuring 10–22 mm in shell diameter, <50 ind m^{-2} for individuals measuring 25–40 mm and <10 ind m^{-2} for individuals of 40–50 mm. The latter should be released to the reef for natural development in the wild. Suitable culture sites are coral reefs, with limited wave action, high water transparency, and availability of rubble or rocks covered with algae. Cage culture is the most effective culture method because it is easily managed and cages can protect topshells from waves, wind and predators. The preliminary results presented here are from the first study on this species in Vietnam, thus providing the basis for topshell stock enhancement in this country.

Introduction

Trochus, or topshell (*Trochus niloticus* Linne, 1767), is a mollusc that is found on coral reefs of the Indo–Pacific. It can reach up to 13 cm in shell height, and the shell diameter ranges from 50–60 mm at two years of age. This species is economically valuable in terms of food, and the shell is used to produce crafts and cosmetics. The main topshell exporting countries are Indonesia, the Philippines and Thailand, with Japan, Hong Kong and Europe being the biggest consumers. Production of trochus in the Andaman Sea (Thailand) was 1955 kg in 1994–1995; this number decreased to 450 kg in 1995–1996 and rose again to 4382 kg in 1996–1997.

In Vietnam, *Trochus niloticus* has been exploited for its meat and shell. Current market prices are between 40,000 and 70,000 Vietnamese dongs (VND)[2] per shell sold as handicraft, and VND 150,000 kg^{-1} for the meat. Nowadays, due to high demand for the shell, overexploitation of trochus has resulted in resource exhaustion. *T. niloticus* is one of the protected species listed within Vietnam's Red Book (MOST 2000) and by CITES. The habitat of topshell and other marine species has been destroyed. Hence, resource rehabilitation and stock enhancement are necessary, both locally and globally. One effective solution for recovering trochus resources is artificial breeding and the release of larvae and juveniles back into the field (Amos 1992; Ponia 2000; Lee 2000).

Studies on the biology and ecology of *T. niloticus* have been conducted in Indonesia, Thailand, Japan, Micronesia and Australia. Some of the results of these studies can be applied to rearing trochus (Bour 1988; Shokita et al. 1991; Dobson and Lee 1996). The main diet of trochus consists of seaweeds that are easily collected in tidal areas. Rehabilitation and stock enhancement of trochus do not require high financial investment, as they can be conducted in the natural environment.

The specific objective of this project was to artificially breed *Trochus niloticus* for stock enhancement. This paper presents preliminary results of experiments on using hatchery-reared juveniles to enhance stocks of the topshell, *T. niloticus*, in Vietnam.

Materials and methods

Study area

This study was carried out at Chao Reef (12°22′39″S, 109°18′18″E), in the Dam Van hamlet, Ninh Van commune, Ninh Hoa district, Khanh Hoa province

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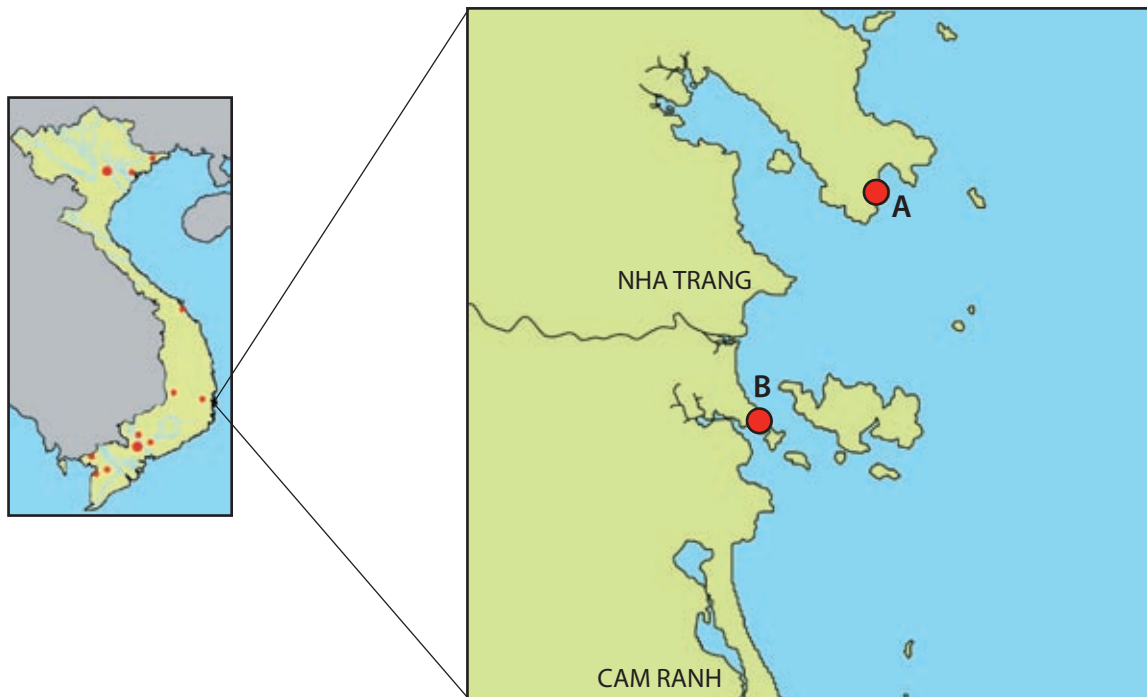2. VND 10,000 = USD 0.62 (July 2007)

Figure 1. Vietnam and a closeup of the study area.
A: Ran Chao Reef, where restocking experiment took place;
B: Institute of Oceanography, where trochus were bred.

of Vietnam (Fig. 1). The site is approximately eight hectares. In recent years, trochus were present at Chao Reef, but they have since completely disappeared due to overexploitation.

Trochus culture cages were placed on the northern side of Chao Reef on the sand and rubble bottom, at the reef base where there is less wave action.

The seaweed and algal composition of Chao Reef includes: *Lyngbya aestuarii, Lyngbya lutea, Ocillatoria* sp., *Acanthophora spicifera, Galaxaura arborea, Gelidium pusillum, Gracilaria edulis, Hypnea pannosa, Lorencia composita, Feldmannia* sp., *Dictyota dichotoma, Dictyota bartayresii, Padina australis, Enteromorpha* sp., *Amphiroa foliacea, Galaxaura ablongata, Laurencia composita, Padina japonica, Sargassum* spp., *Caulerpa racemosa, Enteromorpha* sp., *Halimeda opuntia*.

Experimental research

Trochus niloticus juveniles were obtained from artificial breeding in the laboratory at the Institute of Oceanography. They were transported by boat to the site (around 2 h).

Cage culture at different densities

Trochus were cultured in cages (1 x 1 x 0.6 m) consisting of iron bars (14 mm in diameter). Each cage was surrounded by a nylon net (4 mm mesh size).

Seaweed and algae growing on dead corals or rocks were used as food. The dead coral and rocks were collected in adjacent areas and placed inside the culture cages to cover about 70–85% of the bottom area. Food was changed and cages cleaned three times a month.

Experiment 1 (17 August to 4 October 2003)
The three culture densities tested were 50 ind m^{-2}, 100 ind m^{-2} and 250 ind m^{-2}, beginning with an initial size of 8–12.5 mm shell diameter. The mean diameter (DK) was 10.59 ± 1.30 mm (S.D.) and body weight was 0.37 ± 0.14 g (S.D.).

Experiment 2 (4 November 2003 to 10 June 2004)
Culture densities were 50 ind m^{-2} and 100 ind m^{-2}. The initial size (shell diameter) of the trochus was 22.90 ± 1.74 mm and 22.28 ± 2.44 mm (S.D.), respectively for each treatment.

Experiment 3 (9 July to 10 September 2004)
Culture densities were 10 ind m^{-2}, 20 ind m^{-2}, and 40 ind m^{-2}. The initial size (shell diameter) of the trochus was 39.83 ± 3.61 mm, 39.92 ± 4.40 mm and 43 ± 5.32 mm (S.D.), respectively. Measurements of growth and survival were recorded monthly.

Effect of food quantity on growth rate

Experiment 4 (August to November 2004)
Initial size (shell diameter) was 15 mm and culture

density was 60 ind m^{-2}. Treatments consisted of no food, food covering 50% of the cage bottom, and food covering 100% of the bottom. Each treatment was represented in three replicates.

Experiment 5 (July to November 2004)
Initial size (shell diameter) was 40.18 ± 2.48 mm and culture density was 15 ind m^{-2}. Treatments consisted
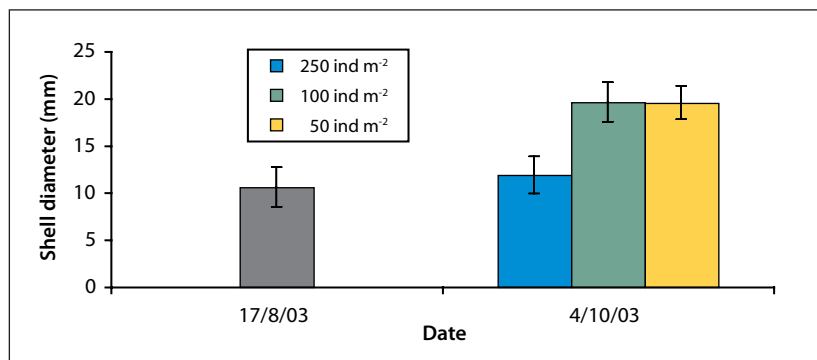

Figure 2. Initial size (17/8/03) and final sizes (4/10/03) of trochus cultured at different densities (50 ind m^{-2}, 100 ind m^{-2} and 250 ind m^{-2}).
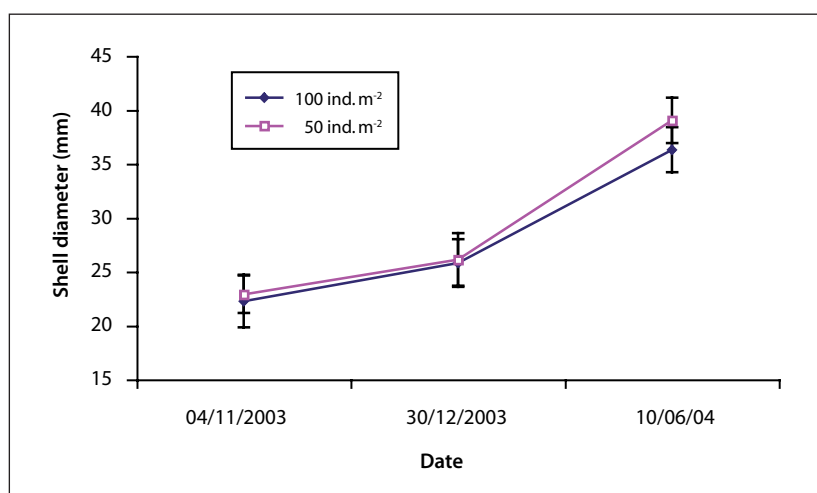
Figure 3. Growth of trochus cultured at different densities (50 and 100 ind m^{-2}).
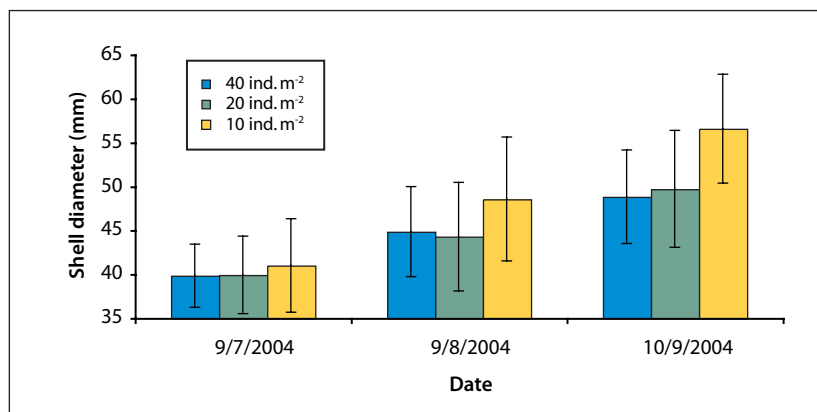
Figure 4. Growth of trochus cultured at different densities (10 ind m^{-2}, 20 ind m^{-2} and 40 ind m^{-2}).

of no food and food covering 20%, 40%, 65% and 90% of the cage bottom.

Results

Data on the number of trochus remaining in the culture cages, basal diameter and weight were collected on a monthly basis. Results are expressed as mean ± S.D.

Cage cultures at different densities

Experiment 1
Initial size (shell diameter) of the trochus was 10.59 ± 1.30 mm. After 1.5 months, growth rates of trochus cultured at a density of 100 ind m^{-2} were no different from those cultured at 50 ind m^{-2} and trochus in both treatments grew faster than trochus cultured at a density of 250 ind m^{-2} (ANOVA, $p < 0.001$) (Fig. 2). Furthermore, the survival rate at 50 ind m^{-2} was the highest (100%), followed by 73% at 100 ind m^{-2} and nearly 20% at a density of 250 ind m^{-2}.

Experiment 2
After seven months, trochus at densities of 100 ind m^{-2} and 50 ind m^{-2} grew from an initial size of about 22 mm to 36.31 ± 2.08 mm and 39.04 ± 2.11 mm, respectively, with no significant difference between the two treatments (t-test, $p > 0.18$) (Fig. 3). Survival was 79% and 100% for trochus cultured at 50 ind m^{-2} and 100 ind m^{-2}, respectively.

Experiment 3
After two months, the final sizes measured were 48.82 ± 5.33 mm at a density of 40 ind m^{-2}, 49.72 ± 6.66 mm at 20 ind m^{-2}, and 56.57 ± 6.2 mm at 10 ind m^{-2}. Survival was greater than 90% for all three treatments. No significant difference in growth rate was found between densities of 20 ind m^{-2} and 40 ind m^{-2}, but significant differences were observed between 10 ind m^{-2} and the two other densities (Fig. 4).

Effect of food quantity on growth rate

Experiment 4
The trochus in this trial had an initial size of 15 mm and reached about 26 mm in four months. There was no significant difference in growth rate between the treatments (i.e. 0%, 50% and 100% food covering on the cage bottom) (ANOVA, p> 0.05) (Fig. 5).

The animals grew well but the mortality rate was higher in the cages without any food compared with the others. The reason may be a lack of food in the initial growth stage. There was no significant difference in the survival rate of the trochus in cages with 50% and 100% cover, but both groups showed significant differences in comparison to the survival of trochus in the treatment with no substratum (Fig. 6).

Experiment 5
This experiment was conducted at a density of 15 ind m^{-2} with all individuals having a shell diameter of 40.18 ± 2.48 mm and a weight of 20.08 ± 3.96 g. In cages with no food, trochus fed on seaweed attached to the walls. In other cages, trochus were further supplied with different amounts of seaweed attached to dead corals. Survival rates were greater than 90% in all treatments. Trochus cultured with more food grew faster (Fig. 7).

There were significant differences among the growth rates of trochus cultured with different covers of food/substrata: 90% > 65% > 40% > 20% > no substrata (ANOVA, p < 0.02). Results showed that trochus cultured in cages supplied with food covering 90% of the bottom yielded the greatest sizes, weight and growth rates. In contrast, trochus in cages with no rocks or additional food showed the slow-
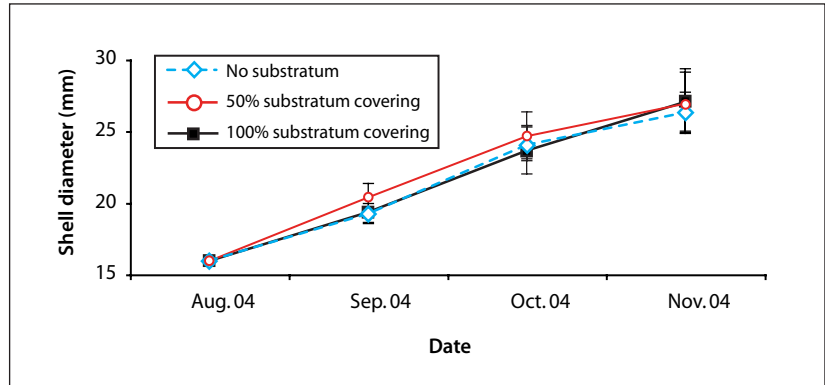

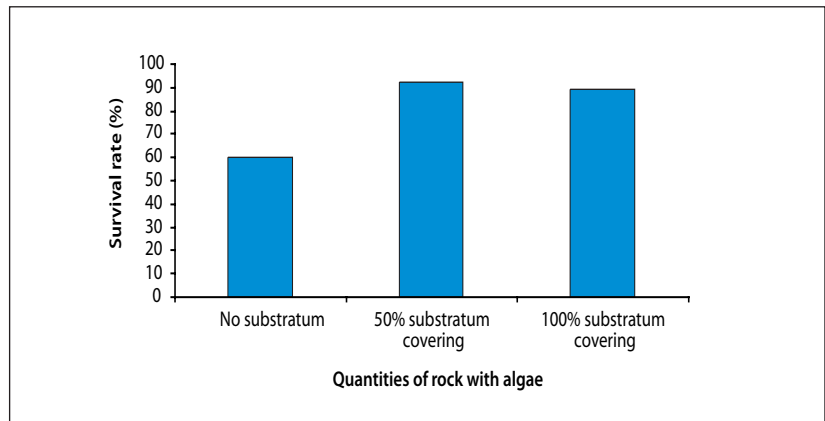**Figure 5.** Growth of trochus with different amounts of food supplied.

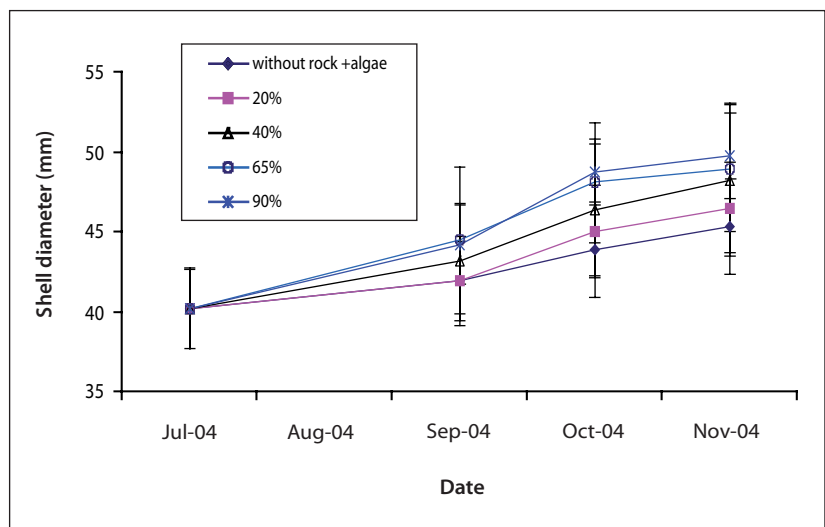**Figure 6.** Survival rate of trochus with different amounts of food supplied.

Figure 7. Growth of trochus with different amounts of food supplied.

est growth rate. Survival rates were also higher in cages with additional substrata. The results suggest that a sufficient amount of food supply is essential when trochus are larger than 40 mm (Fig. 7).

Discussion

Trochus generally occur from the littoral zone to depths of less than 5 m, although they have been found at 20 m (Shokita et al. 1991). They usually colonize the windward margins of coral reefs where small seaweeds are abundant around rubble in the littoral zone (Trochus cannot survive on sandy and muddy bottoms (Nash 1985)). The study area at Chao Reef was a rocky reef flat with algae present, and the results of the culture experiments indicate that this is an appropriate site for trochus restocking.

Our data show that small trochus grew faster than larger ones. The growth rate of trochus was higher in the dry season (March to October) than in the rainy season (November to March) when low temperatures, windy conditions, and increased wave action yielded lower survival rates.

During the rainy season, runoff from land carries sediment into the nearby seawater making it opaque. This sediment accumulates in the cages and may have an adverse effect on the growth of seaweed, resulting in a lack of food for cultured trochus. However, in the dry season, there is little runoff and the seawater is clear of sediments, allowing seaweeds to grow well on cages, and trochus to have access to sufficient food. It was easier to collect and change seaweed-covered rocks on a regular basis in the dry season so that trochus grew faster.

The very high survival rate (usually over 75%) in almost all the cage culture experiments, irrespective of density, indicates that trochus are able to adapt to the conditions at Chao Reef. On the other hand, the initial size of the trochus was a major factor affecting the survival rate. According to Isa et al. (1997) culturing trochus larger than 30 mm usually results in high survival rates because of the animal's increased resistance to predators and negative environmental conditions.

It is recommended that culture densities be adjusted depending on the initial size of the trochus (Table 1). At a shell diameter of 10–22 mm, trochus can be cultured at a maximum density of 100 ind m^{-2}. When trochus reach 25–40 mm, the density should be reduced to less than 50 ind m^{-2}. When trochus reach 40–50 mm, they should be cultured at densities lower than 20 ind m^{-2}, down to 4–7 ind m^{-2} for trochus larger than 50 mm.

Table 1.   Size and density recommendations for trochus culture.

Basal diameter (mm)	Density in cages (ind m^{-2})
10–20	100
25–40	50
>40	<10

In cages which were not supplied with dead corals or rocks covered with algae, trochus grew quite well during the first stage of culture. In these cages, the food source was local seaweed and algae that naturally grew on the cage's walls. However, quantities of this kind of food are limited, so that the culture density is a critical factor that affects the growth and survival at later stages. Results from our experiments indicate that trochus less than 20 mm shell diameter can be cultured in cages at Ninh Van at densities less than 100 ind m^{-2} without adding food. When replacing substratum/food every 10 days, the cover of suggested substratum is about 50% at a density of 60 ind m^{-2} for trochus 15–25 mm.

Food plays an important role in the growth of cultured trochus. With smaller specimens (<30 mm), seaweed attached to rocks that cover more than 50% of the cage bottom need only be provided at the beginning of the culturing process. When trochus are larger than 30 mm, they need the food supply to be renewed two to three times a month by replacing the seaweed-covered rocks, and maintaining a cover of more than 50% of the bottom area.

In general, the commune governor, participants, and the local community positively supported the project and acted responsibly in working together with scientists during the course of the trochus culture experiments at Ninh Van. Interviews and meetings with local people revealed that the natural resources at Ninh Van have been degrading. People were interested in and ready to support research activities aimed at rehabilitating natural resources in general and trochus in particular. The hope is to develop a suitable culture model to improve living standards, manage coral reefs, and restore marine resources.

Cage culture appears to be an appropriate method because it is easy to manage and it reduces the

negative impact of predators. Trochus grew well when food in the form of seaweed-covered rocks was supplied. Results show that culture densities depend on the size of trochus, with lower densities suitable for larger animals (Table 1).

Predators, possibly crabs, killed some trochus during our experiments. The damaged shells are shown in Figure 8. According to Isa et al. (1997), predators are the principal factor affecting the survival rate of trochus. Main trochus predators include:

- crustaceans (e.g. crabs — *Mancinella tuberosa*, *Calappa hepatica*), mantis shrimp (*Gonodactylus chiragura*),
- molluscs,
- flatworms (e.g. common species are *Pericelis byerleyana* and *Planocera reticulata*), and
- fish (mainly porcupine fish, Diodontidae).

Diodontidae are the most dangerous threat to cultured trochus under laboratory conditions. However, in nature, Diodontidae are not abundant in areas where trochus occur or are cultured. Therefore, the threat that Diodontidae pose to cultured trochus is low. Flatworms, often found on rocks in the littoral zone, attack trochus at night. Therefore, removing flatworms from the substrata is a necessary precaution before starting a culture. Mantis shrimp and crabs can crush the shell and ingest trochus. They are common predators found in the littoral zone, in areas of trochus culture. Trochus are more susceptible to predators when they are young, especially when they are less than 10 mm in shell diameter. However, when the shell diameter exceeds 17 mm, the animal's defensive capabilities are much higher.

Figure 8. Trochus shells damaged by predators during experiments at Chao Reef.

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Development and movement of the opisthobranch, *Hydatina physis*, in the Solomon Islands

Jean-François Hamel[1] and Annie Mercier[2]

Abstract

This study investigated several aspects of the life history of the opisthobranch, *Hydatina physis*, including the circadian foraging cycle, monthly breeding activity, development, settlement preferences and growth, using laboratory trials and field observations. We have recently published results on the nocturnal circadian rhythm mediated by photic intensity and modulated by food availability (Hamel and Mercier 2006). The present study further showed that the average absolute distance covered daily was around 471 cm. All individuals exhibited apparently random movements, changing direction after each surfacing, although a degree of homing behaviour was apparent. The courtship, copulation, egg-laying and hatching of *H. physis* was primarily influenced by the lunar cycle (Hamel and Mercier 2006). Each capsule contained between 0 and 14 eggs and/or embryos. In almost all capsule masses, abnormal development and high mortality rates were observed in the first third of the capsules released. In part of the mass that developed normally, veligers developed around 3 days after capsule-laying. They emerged from the capsules and began to feed on phytoplankton about 2 days later, settled after 7.5–9 days, and reached a size of around 4 mm after 5.5 months.

Introduction

The green-lined paperbubble, *Hydatina physis* Linnaeus, 1758, is an opisthobranch gastropod that is found circum-globally in shallow tropical waters of the Atlantic and Indo-Pacific Oceans (Rudman 1972; Kilburn and Rippey 1982; Wirtz 1999; Abbott and Dance 2000). Even though *H. physis* is widely distributed and is attractive to aquarists and shell collectors (Kilburn and Rippey 1982), data on its biology remain scarce and mostly anecdotal. According to Beeman (1977), opisthobranch populations tend to be sporadically explosive, which can partially account for the rarity of published data on their reproductive habits.

We have recently found that adult *H. physis* express a well-defined activity cycle (Hamel and Mercier 2006). The majority of individuals remain burrowed in sand for ca. 12 h each day, surfacing at dusk to forage during the night with only short periods of re-burrowing. Because individuals surface at sunset and burrow at sunrise, a photically entrained circadian rhythm is the most probable underlying factor. Apart from their nocturnal burrowing habits, adult *H. physis* display a well-marked mobility pattern with a maximum distance recorded between 20:00 and 22:00, followed by a progressive decrease in the distance travelled until the next morning (Hamel and Mercier 2006).

Our earlier study also revealed that the reproduction of *H. physis* follows a lunar periodicity and that larval settlement preferably occurs on substrata that are rich in food items sought by the adults (Hamel and Mercier 2006). For four consecutive months, hermaphroditic reciprocal copulation, preceded by pre-copulatory courtship behaviour, occurred at night, 5–7 days (d) before the full moon. Spawning occurred 3–5 d later for up to five consecutive nights, the egg mass gradually decreasing in size with each spawning. An overcast sky or rain prevented or delayed both copulation and egg release. Settlement of veligers was largely influenced by the nature of the substrate. In multiple-choice experiments, settlement occurred predominantly on sand containing cirratulid polychaetes. Juveniles reached around 3.9 mm in shell length after 5.5 months (mo) of growth (Hamel and Mercier 2006).

The present paper provides complementary data that further elucidates the movement patterns of *H. physis* and provides details on the larval development until metamorphosis into juvenile.

Methods

Numerous *H. physis* specimens (Fig. 1) were commonly found in the intertidal zone off Aruligo, Solomon Islands (9°25.59′ S and 159°56.58′ E). For laboratory trials, individuals were collected on the

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Figure 1. The green-lined paper bubble, *Hydatina physis*, in its natural
environment at night. Shell length of this specimen
is approximately 4 cm.

Whenever egg-laying was observed, groups of capsules were collected at regular intervals from at least three different masses. Samples were collected every 2–5 minutes (min) during the first 2 h, then every hour for the next 12 h, twice daily for 7 d and approximately once a day for the remainder of the trial. Some of the capsules were observed live and others were preserved in 4% formaldehyde/sea water for subsequent morphological examination and measurements. Capsules were routinely collected in two different sections of the mass to compare their development and mortality rates: close to the anchor (i.e. among the first released) and at the distal tip (i.e. among those released last). Between 20 and 25 embryos were sampled from capsules in both locations within each mass. Sizes were measured under a light microscope equipped with a graduated ocular. A new stage was considered attained when 50–60% of the embryos and/or larvae reached it. The egg masses under observation were not moved for the duration of development.

sand at low tide, or in tide pools, and immediately transferred to holding tanks. Whenever possible, all observations were concurrently carried out in the field and in the laboratory. For details on the collection, maintenance and experimental procedures, see Hamel and Mercier (2006).

Movements of adult *H. physis* were monitored by making a slight mark on the shell of 11 specimens prior to the trial to allow identification. Every 2 h, the position of each specimen was marked (using a small numbered plastic flag) and its general behaviour (i.e. moving, burrowing, surfacing) was noted. The absolute distance traveled by an individual over the 2-h interval was measured as the distance between two consecutive flags. All individuals were followed for three clear days, as well as during rainy or overcast days. Movement and orientation of *H. physis* were tested for randomness with the Rayleigh test. The directionality of movement by individuals was examined with a second-order analysis, which allowed inferences to be made about the populations of individuals examined. In this case, the cumulative frequency distribution of the length of the mean vector "r" (the Rayleigh statistic) of each individual's direction of movement was compared with the theoretical distribution of "r" for the same sample size by the Kolmogorov-Smirnov goodness of fit test (Batschelet 1981).

Results

Movements

Globally, all *H. physis* exhibited apparently random displacements (Rayleigh test of directionality, p>0.05), changing direction after each surfacing and every day. The only recurrent pattern was observed in the 22:00 records, which systematically corresponded to the outside most positions (Fig. 2) at the end of the peak locomotor activity period.

Embryonic and larval development

Embryonic development was not entirely synchronous between various parts of the capsule mass (Table 1). In the central section of the rosette, which harbours the capsules that were spawned first (i.e. close to the anchor), up to 85% of the embryos developed abnormally, compared with 5–10% in the capsules located farther from the anchor. The time course of normal development is shown in Table 1. Although the approximately 10,000–30,000 capsules
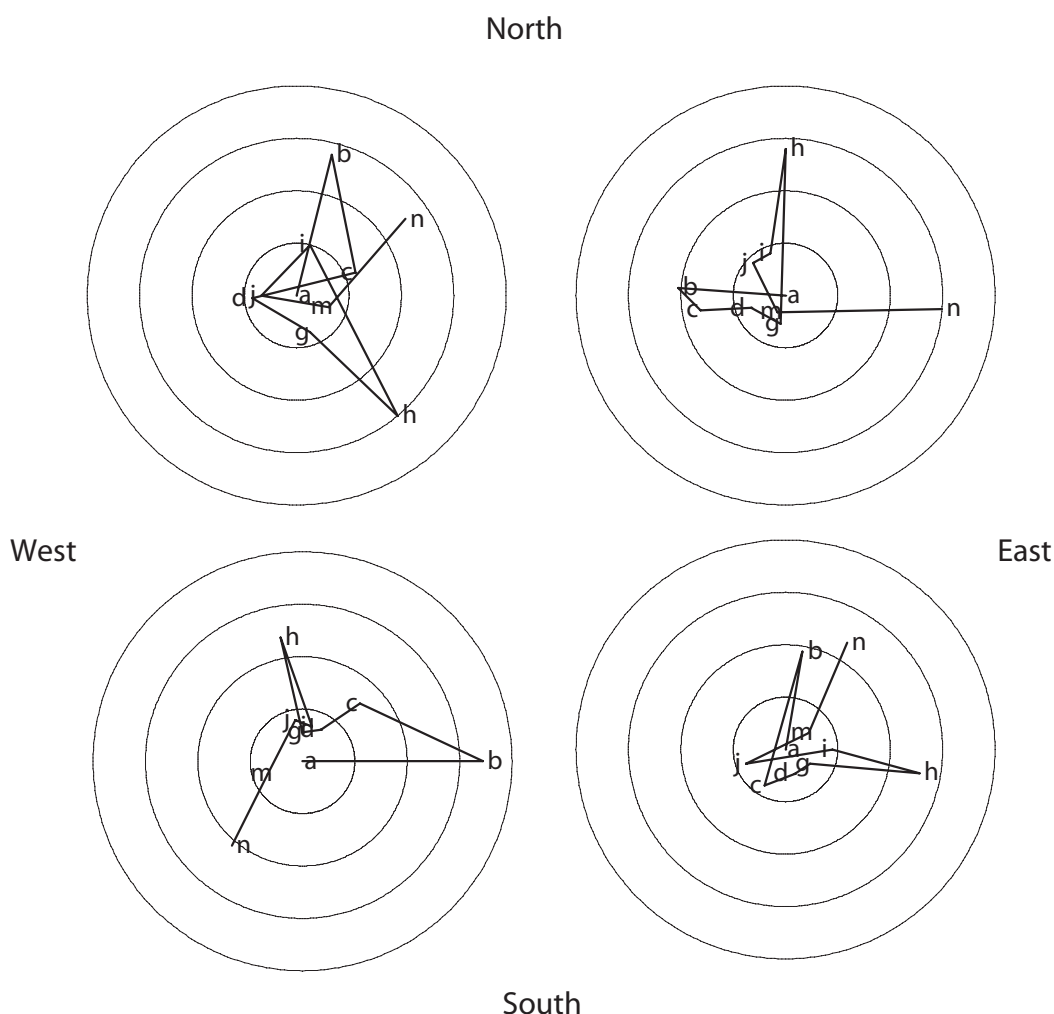
North

West

East

South

Figure 2. Absolute displacement of four *Hydatina physis* individuals under clear conditions (<30% cloud cover). Positions were recorded every 2 h for 3 d, but for the sake of clarity, data are shown at 4-h intervals for the first 52 h. The letter "a" corresponds to initial time (18:00 on day 1) and the letter "n" to the last value recorded (22:00 on day 2). Note that "b" and "h" are the two other 22:00 values.

near the anchor were spawned first, the development of their embryos was slower, and the asynchrony in development increased with time. Moreover, the first capsules contained embryos that did not develop into veligers and consequently never hatched. In normally developing capsules throughout the mass, most of the embryos developed synchronously (Table 1).

H. physis had telocithal eggs with holoblastic (or total) cleavage, the first two divisions being equal and the third unequal. The first cleavage was vertical through the animal and vegetal poles of the embryo, dividing it into two blastomeres of equal size. The fertilized oocytes measured about 50 µm in diameter. At the 2-cell stage, the embryos reached a diameter of 67 µm. The second cleavage was also vertical, perpendicular to the first and began about

30 min after fertilization, forming four symmetrically arranged blastomeres of equal size. Another cleavage took place 10 min later in the horizontal plane and at right angles to the two earlier cleavages, forming four micromeres and four macromeres. A short time thereafter, the embryos underwent an additional division of the macromeres, thus producing four more micromeres.

As development proceeded, the micromeres piled up and formed a pointed dome at the animal pole. About 9 h after fertilization, the numerous micromeres extended over almost the entire surface of the embryo, leaving only a small area of the macromeres uncovered. This was the blastula stage. After 34 h, the larva emerged from the fertilization envelop as a late gastrula (Table 1). After 42 h of development, the larva was slightly tapered

Table 1.   Development of *Hydatina physis*. A new stage was considered attained when around 50–60% of the embryos/larvae reached it. Temperature varied with the daily cycle between 25°C (night) and 29°C (day). Data pooled from seven different spawning events are expressed as mean ± S.D.

Time	Typical development throughout the egg mass		
	Stage	Capsule diameter (µm)	Embryo/larva diameter (µm)
0	Fertilization	230 ± 30	49 ± 4
15 min	1-cell	230 ± 35	58 ± 5
30 min	2 cell	284 ± 45	67 ± 5
60 min	4-cell	250 ± 50	66 ± 6
70 min	8-cell	255 ± 55	66 ± 5
85 min	16-cell	250 ± 40	63 ± 5
95 min	Division stage	245 ± 50	83 ± 7
5 h	Division stage	245 ± 35	81 ± 4
6 h	Division stage	250 ± 40	84 ± 5
9 h	Early blastula	240 ± 35	75 ± 5
16 h	Late blastula	260 ± 50	76 ± 6
31 h	Gastrula	255 ± 45	78 ± 5
34 h	Hatching from fertilization envelope	250 ± 40	69 ± 4
42 h	Trochophore	275 ± 40	89 ± 4
50 h	Late trochophore (early shell development)	280 ± 35	93 ± 3
3 d	Early veliger	285 ± 50	100 ± 7
3.8 d	Veliger spinning in capsule	390 ± 65	110 ± 8
4.9 d	Veliger hatching from capsule	410 ± 32	111 ± 9
7 d	Veliger (extrusion of muscular foot, searching behaviour)	-	112 ± 8
7.5–9 d	Metamorphosis and settlement	-	109 ± 4
7.9–9.5 d	Juvenile	-	112 ± 3
2 wk	Juvenile	-	145 ± 7
1 mo	Juvenile	-	211 ± 9
2 mo	Juvenile	-	485 ± 42
3 mo	Juvenile	-	1543 ± 140
5.5 mo	Juvenile	-	3900 ± 310

at the anterior end, which displayed a small tuft of short cilia that enabled the larva to rotate and move backwards and forwards. This was the trochophore stage. About 24 h later two large, ciliated lateral lobes and a smaller median lobe with shorter cilia developed. The foot also developed posterior to the ciliated lobes. Beneath it, near the base, was a short, pointed operculum. Furthermore, the shell began to form around the posterior part of the body. About 3 d after fertilization, the larva had a well developed shell with an operculum and a bilobate ciliary tuft, typical of the veliger stage (Table 1).

Upon reaching the veliger stage, the larvae began to spin within the capsule at a rate of 1 revolution s^{-1}, thus disintegrating the residual underdeveloped embryos (representing <5% of all eggs/embryos in a capsule). The resulting small fragments and lipid droplets were ingested by the developing veligers, filling their digestive tracts. At the same time, the capsules grew from 285 to 390 µm in diameter. At the veliger stage, the ciliary rings of the velum oscillated without interruption. Four days after fertilization, the veliger displayed circular movement and the capsules reached 410 µm in diameter. The swimming-veliger hatched from the capsule after 4.9 d of development to enter the pelagic stage (Table 1). Immediately after hatching, the free-swimming veliger began to swim in the water column, near the surface. Approximately 2 d later, the veliger started to exhibit a searching behaviour by repetitively touching the bottom. At this time, its swimming capacity decreased considerably; the two well-developed ciliary lobes atrophied to form a tuft between the shell and the closing operculum. This searching period lasted around 1–2 d before settlement occurred after 7.5–9 d of development. Juveniles reached a size of 4 mm after 5.5 months.

Discussion

Movements

Adults foraged between 19:00 and 05:30, with an activity peak between 20:00 and 22:00, and remained inactive and burrowed in the sand during the day. This pattern was clearly influenced by cloud cover, rain and laboratory manipulated light:dark cycle (Hamel and Mercier 2006). Circular plotting of the data over three consecutive days hinted at the occurrence of a homing behaviour, the individuals showing a strong tendency to forage on the periphery of the tanks and to rest and/or bury closer to the central area where they were initially placed. As field and laboratory observations were carried out in the presence of large amounts of potential food items (i.e. cirratulids; Rudman 1972), the first intense foraging phase after sunset may have fulfilled most of the nutritional requirements of *H. physis*,

thus lessening the need for further activity. However, intestinal contents were not examined to confirm this hypothesis.

Development

In opisthobranchs, development from egg-laying to hatching takes an average of 11 d (Hadfield and Switzer-Dunlap 1984). The short period in *H. physis* (5 d) may be partly attributable to the warm water in which the embryos and/or larvae develop. However, growth and mortality rates in *H. physis* differed considerably according to the location of the capsule in the rosette. Deformities and abnormal development were predominant in the first third of the spawned capsules, generally those located close to the anchor. This was observed in all the egg masses examined, and could be due to polyspermic fertilization. Such abnormality was not evident in the last two-thirds of capsules released. The spermatozoa:oocytes ratio may be controlled less efficiently at the beginning of the laying period than later in the process.

There may be nutritional benefits to encapsulation, particularly in marine gastropods, in which encapsulating structures enclose extra-embryonic yolk or nurse eggs in addition to developing embryos (Thorson 1950; Spight 1976; Rivest 1983; Pechenik 1986). Veligers of *H. physis* were observed to ingest fragments of dying embryos, which represented <5% of the total in nearly all capsules observed, although this does not seem to be a common trait in opisthobranchs. The presence of these dying or fragmented embryos did not seem to impede the growth and hatching of normal larvae but their possible role as food for surviving embryos remains to be clarified.

The release of offspring from encapsulating structures has been described for a number of molluscs (Vaughn 1953; Davis 1967; Gamulin 1973; West 1973; Pechenik 1975; Webber 1977), although Pechenik (1986) mentioned that the hatching process remains poorly understood. While chemical mediation of hatching has been documented in the marine gastropod *Ilyanassa obsoleta* (Sullivan and Bonar 1984; Sullivan and Maugel 1984), the rotation of the growing larvae, the enlargement of the capsules and their non-uniform rupture support a mechanical process in the case of *H. physis*.

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Abstracts & publications

Management options for restocked trochus fisheries

S. Purcell

Source: K.M Leber, S. Kitada, H.L Blakenship, T. Svåsand (eds). 2004. Stock enhancement and sea ranching: developments, pitfalls and opportunities. 2nd Edition. Blackwell Pub., Oxford. p. 233–243.

Methods for restocking trochus fisheries have advanced greatly in recent years but restocking activities must link to sound management schemes to ensure sustainability of trochus fisheries. Management schemes generally have greater acceptance and persistence if these are community-based and enforced at a local level. Plans for seasonal or periodic closures, quotas and size limits need to be location-specific due to regional differences in trochus demography and traditional management approaches. Marine Protected Areas (MPAs) or No-Take Zones should be established at multiple sites for restocking trochus and preserving breeding populations. Fishing grounds should be protected for at least 5 years for recovery of sustainable stocks and fishing should commence on the basis of favourable stock assessment. Slot limits allow trochus 1–2 spawning years before reaching legal size and protect the very large individuals. Provided that fishers comply with size limits, MPAs and community-based management schemes should allow restocked trochus to replenish fisheries, leading to increased, sustained harvests.

Rapid recruitment of corals on top shell snail aquaculture structures

M. Omori, H. Kubo, K. Kajiwara, H. Matsumoto, A. Watanuki

Source: Coral Reefs 25(2): 280. May 2006.

No Abstract.

Using impact assessment methods to determine the effects of a marine reserve on abundances and sizes of valuable tropical invertebrates

M.P. Lincoln-Smith, K.A. Pitt, J.D. Bell, B.D. Mapstone

Source: Canadian Journal of Fisheries and Aquatic Sciences 63(6):1251–1266. June 2006.

Procedures for impact assessment, including "beyond-BACI" (before-after control-impact) and proportional differences (ratios between impact and control treatments) were used to test population replenishment of marine invertebrates at a marine conservation area (MCA) and three fished (control) areas in the Solomon Islands of the southwestern tropical Pacific. Within shallow reef terrace habitat, the MCA caused abundance and size of the topshell *Trochus niloticus* to increase but did not affect holothurians (sea cucumbers) or the giant clam *Tridacna maxima*. Abundance of the nonexploited topshell *Tectus pyramis* was unchanged at the MCA but increased at the controls, possibly because of changes in abundance of *T. niloticus*. Within deep slope habitat, the MCA caused increased abundance of the sea cucumber *Holothuria fuscogilva* and prevented possible declines in abundances of *Thelanota anax* and all holothurians combined but had no effect on abundances of *Holothuria atra* or *Holothuria fuscopunctata*. Power analysis comparing the MCA with controls indicated that further, relatively modest increases in abundance or size of some species would have a good chance of being detected statistically. The beyond-BACI procedure holds promise for enabling rigorous evaluation of marine reserves as management tools at different spatial scales; the use of proportional differences is simpler but has limited management value.

Diseases of pearl oysters and other molluscs: a western Australian perspective

J.B. Jones, J. Creeper

Source: Journal of Shellfish Research 25(1):233–238. April 2006.

Mollusc culture, particularly the cultivation of pearl oysters, is an important component of the aquaculture industry in Western Australia. As a result, there has been a long-term investment in surveys of commercial mollusc species for potential diseases of concern. A number of pathogens, particularly haplosporidans, identified within wild-stock shellfish have the potential to adversely affect mollusc populations. Others pose risks for translocations associated with aquaculture. The microsporidan *Steinhausia mytilovum* (Field),

found in ova of the blue mussel *Mytilus galloprovincialis* (Lamarck), poses intriguing questions about the origin and dispersal of its host.

New and little-known gastropods from the Albian of the Mahajanga basin, northwestern Madagascar

S. Kiel

Source: Journal of Paleontology 80(3):455–476. May 2006.

Thirty-one gastropod species and one type of isolated larval shell are described from a quarry near Ambatolafia in the Mahajanga Basin, northwestern Madagascar. The ammonite fauna indicates a lower Albian age of the fauna (*Cleoniceras besairiei* Zone). The taxonomic position of the species described earlier is reviewed, incorporating new data on shell structure and protoconch morphology. Twelve species and one genus are new, with four species described in open nomenclature. The oldest hitherto known representatives of *Cocculina* sensu lato, *Iphitus*, *Conjectura*, *Entomope*, *Tomura*, and possibly *Vatopsis* and *Paladmete*, are described. Nacre is documented in a species of *Semisolarium*, providing further evidence for the position of this genus within the Vetigastropoda. Eight of the species occur also in the Cretaceous of Europe or are tentatively assigned to European species. Three species have close relatives in the Aptian/Albian of Japan, one species may have relations to the Albian of Texas. The new genus is *Mahajangina* (family uncertain) for a species having a small, trochispiral teleoconch with spines on the periphery, and a conical, bicarinate larval shell. The new species are: *Cirsocerithium collignoni*, *Zardinistylus betsibokaensis*, *Pommerozygia mahajangensis*, *Conjectura minuta*, *Buvignieria berwaldi*, *Mahajangina weitschati*, *Entomope crassilabrum*, *Paladmete? rasoarinoroae*, *Tomura ambatolafiensis*, *Carinathilda parviruga*, *Carinathilda bandeli*, and *Gymnothilda pagodoidea*.

Virus-like particles associated with mass mortalities of the pen shell *Atrina pectinata* in Japan

Maeno Y., Yurimoto T., Nasu H., Ito S., Aishima N., Matsuyama T., Kamaishi T., Oseko N., Watanabe Y.

Source: Diseases of Aquatic Organisms 71(2):169–173. 2006.

Mass mortalities of the pen shell *Atrina pectinata* occurred in the fishing grounds of Ariake Bay, in southwestern Japan, during late spring and summer in 2003 and 2004. Histological examination revealed extensive necrosis in the epithelial cells of the kidney and gill, and impairment of the endothelial cells of the mantle arteria. Although cestode larvae belonging to the genus *Tylocephalum* were found in the mantle, adductor muscle, kidney, and digestive gland, their prevalence and the intensity of infection were low. Examinations of moribund pen shells for *Haplosporidium* spp. infection using PCR analysis and for *Perkinsus* spp. infection using Ray's fluid thioglycollate medium were negative. Unenveloped virus-like particles were detected by transmission electron microscopy in the cytoplasm of affected kidney and gill cells of moribund pen shells. They were icosahedral spherical and 50 to 55 nm in diameter. These virus-like particles found in moribund pen shells are different from those described in other marine mollusks, and may be the causative agent of the mass mortalities of pen shells.

The intersection of scientific and indigenous ecological knowledge in coastal Melanesia: implications for contemporary marine resource management

S. Foale

Source: International Social Science Journal 58(187):129–137. March 2006.

Fundamental differences in the worldviews of western marine scientists and coastal Melanesian fishers have resulted in very different conclusions being drawn from similar sets of observations. The same inductive logic may lead both scientists and indigenous fishers to conclude that, say, square-tail trout aggregate at a certain phase of the moon in a certain reef passage, but different assumptions derived from disparate worldviews may lead to very different conclusions about why the fish are there. In some cases these differences have significant implications for the way marine resources are (or are not) exploited and managed. Here I analyse examples of what I call empirical gaps in both scientific and indigenous knowledge concerning the biology and ecology of fished organisms that in some cases have led to the poor management of stocks of these species. I argue that scientific education can complement indigenous knowledge systems and thus lead to improved resource management, despite some claims that scientific and indigenous knowledge systems are incommensurable.

Factors regulating the breeding and foraging activity of a tropical opisthobranch

J.-F. Hamel, A. Mercier

Source: Hydrobiologia 571:225–236. 2006

This study investigated the influence of environmental factors on the foraging cycle, breeding activity, settlement and growth of the opisthobranch *Hydatina physis* using laboratory trials and field observations.

Results showed that *H. physis* follows a nocturnal circadian rhythm mediated by photic intensity and modulated by food availability. The adults foraged between 1900 and 0530 h, with an activity peak between 2000 and 2200 h, and remained inactive and burrowed in the sand during the day. This pattern was clearly influenced by cloud cover, rain and laboratory manipulated light:dark cycle. The reproduction of *H. physis* was primarily influenced by the lunar cycle. For 4 consecutive months, hermaphroditic reciprocal copulation, preceded by pre-copulatory courtship behaviour, occurred at night 5–7 d before the full moon. Spawning occurred 3–5 d later for up to 5 consecutive nights, the egg mass gradually decreasing in size with each spawning. An overcast sky or rain prevented or delayed both copulation and egg release. Settlement of veligers was largely influenced by the nature of the substrate. In multiple-choice experiments, settlement occurred predominantly on sand containing cirratulid polychaetes. The juveniles reached ca. 3.9 mm in shell length after 5.5 months growth.

Manual for the monitoring and management of queen conch

P. Medley

Source: 2005. FAO Fisheries Circular No 1012, Rome, FAO, 58 p.

The Caribbean queen conch *Strombus gigas* is listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). A Listing on Appendix II requires that any specimen of the species included in Appendix II can only be exported if a permit has been issued to allow the export. Further, CITES states that export permits should only be issued when the responsible authority has deemed that the export will not be detrimental to the survival of that species. This manual presents guidelines on the requirements for responsible management of the fisheries exploiting queen conch, with particular emphasis on the requirements to comply with the relevant CITES regulations.

The manual describes the basic fisheries management cycle which includes: development and interpretation of policy; the need for management controls to regulate fishing activities; data collection and analysis; decision-making; enforcement of and compliance with the management controls; and regular feedback and review of the management system. It provides general guidance on each of those steps for the queen conch fisheries of the Caribbean. It also provides two case studies of management systems currently being applied: the Turks and Cairns Islands and Jamaica.

Sections 2 to 6 (Part 1) cover the main issues and examples in a relatively non-technical manner and Sections 7 to 16 (Part 2) cover similar issues in a more technical manner.

Why won't they grow? Inhibitory substances and mollusc hatcheries

J. Jones

Source: Aquaculture International 14(4):395–403. August 2006.

Molluscs are known to be seriously affected by trace amounts of environmental pollutants such as tributyltin at concentrations in seawater that are below the level of detection by all but the most sensitive chemical analytical techniques. This extreme sensitivity by molluscs has led to use of both adults and larvae as biomonitors for environmental pollution. Mollusc aquaculture has led to an increasing demand for commercial hatcheries to supply seed stock, including selected genetic lines of spat and juveniles. It is becoming apparent that many of the unexplained "crashes", ill thrift or failures of larvae to metamorphose in such hatcheries are primarily due to their being compromised for a range of reasons including traces of inhibitory or toxic substances in the water supply. Because dead and dying larvae are ideal substrates for bacterial and ciliate growth, such invaders are often assumed to be the primary cause of the problem and this hinders finding a solution. In addition, many of the toxins which may be implicated in crashes are sporadic in occurrence and are both difficult to detect and hard to remove from the water supply. This paper provides evidence for these toxic effects and suggests ways of reducing the problems.

Population dynamics of the green mussel *Perna viridis* from the high spat-fall coastal water of Malacca, Peninsular Malaysia

S.M. Al-Barwani, A. Arshad, S.M. Nurul Amin, S.B. Japar, S.S. Siraj, C.K. Yap

Source: Fisheries Research 84(2):147–152. April 2007.

Population parameters such as asymptotic length (L_∞), growth coefficient (K), mortality rates (Z, F and M), exploitation level (E) and recruitment pattern of green mussel *Perna viridis* were estimated using length–frequency data from the coast of Malacca, Peninsular Malaysia. Asymptotic length (L_∞) was 102.38 mm and growth coefficient (K) was estimated at 1.50 year^{-1}. Total mortality (Z) for *P. viridis* was 2.48 year^{-1}, while natural mortality (M) and fishing mortality (F) were 1.69 and 0.79 year^{-1}, respectively. The growth

performance index was (φ') 4.197 and the exponent "*b*" of the length–weight relationship was 2.602 (±0.02) during the study period. The asymptotic wet weight estimated from length–weight relationship was 40.81 g. Exploitation level (*E*) of *P. viridis* was 0.32 while the maximum allowable limit of exploitation (*E*$_{max}$) was 0.43. The recruitment pattern was continuous with one major peak in the months of July–August. The exploitation level (0.32) and lower fishing mortality (0.79 year^{-1}) indicate that the green mussel is under-exploited from Malacca coastal waters.

The hatchery culture of bivalves: a practical manual

Helm M.M., Bourne N., Lovatelli A. (Ed.)

Source: FAO Fisheries Technical Paper 471. FAO, Rome, Italy. 184 p. 2004.

Bivalve mollusc culture is an important and rapidly expanding area of world aquaculture production, representing approximately 20 percent of the sector's output at 14 million tonnes in 2000. The majority of production is from natural populations although increasingly stocks are approaching or have exceeded maximum sustainable yields. Stock enhancement through the capture and relaying of natural seed in both extensive and intensive forms of culture is common practice worldwide but the reliability of natural recruitment can never be guaranteed, and conflicts over the use of the coastal zone are becoming ever more pressing. A solution to meeting the seed requirements of the bivalve industry, applicable to the production of high unit value species such as clams, oysters and scallops, is hatchery culture. The production of seed through hatchery propagation accounts at the present time for only a small percentage of the total seed requirement but it is likely to become increasingly important as work continues to produce genetically-selected strains with desirable characteristics suited to particular conditions.

The advent of bivalve hatcheries was in Europe and the United States in the 1960s. Since those early pioneering days, knowledge of the biological requirements of the various species that predominate in worldwide aquaculture production and the technology used to produce them has grown and continues to improve. This manual brings together the current state of knowledge in describing the various aspects of hatchery culture and production from acquisition of broodstock to the stage at which the seed are of sufficient size to transfer to sea-based growout. Focus is on intensive methodology in purpose-built hatchery facilities rather than on more extensive methods of seed production in land-based pond systems. For a complete view, the intermediate nursery phase of production, which is the interface between the hatchery and sea-based growout, and the concept of remote setting are also described and discussed in some depth.

This manual is not intended as a scientific treatise on the subject. Rather, it provides the reader with a practical insight as to what is required in the way of resources and details of how to handle and manage the various life history stages of bivalves in the hatchery production cycle. Examples are largely drawn from the more commonly cultured temperate climate species including the Pacific oyster, *Crassostrea gigas*, the American (Eastern) oyster, *Crassostrea virginica*, the European flat oyster, *Ostrea edulis*, the Manila clam, *Tapes philippinarum* and a range of scallop species. Consideration is also given to the culture of tropical bivalves. Methods described are equally as applicable to bivalves of lesser significance in terms of worldwide production.

The authors recognize that bivalve hatchery production is as much an art founded on science as it is a science per se. There are as many ways of operating and managing a hatchery as there are hatcheries in terms of the sophistication of the facility and the precision with which each part of production is approached. In this respect, many experienced hatchery managers will consider much of the detailed information as "overkill." However, the authors have considered the need for a thorough grounding for new entrants in this field, not just how the various procedures are done but the biological basis of why they are done in that way. Thus, the content is equally as appropriate to the operation of a closely controlled experimental hatchery as it is to a commercial-scale hatchery.

In addition to explanations of culture technology and methodology, the manual includes a brief discussion of the processes of identifying a suitable site for locating a hatchery and considerations in planning and designing the hatchery. It also includes advances that are likely to improve the reliability and economic viability of the hatchery industry in the near future, featuring topics such as polyploidy, the development of selected strains, cryopreservation of gametes and the need for novel, non-living foods.

Managing Jamaica's queen conch resources

K. Aiken, A. Kong, S. Smikle, R. Appeldoorn, G. Warner

Source: Ocean & Coastal Management 49(5-6):332–341. 2006.

Jamaica's industrial fishery for queen conch (*Strombus gigas*) has produced a substantial amount of much-needed foreign exchange and for at least 10 years has been the most valuable component of all commercial

marine fisheries activities. Since its inception in 1990 it has grown tremendously and may now be at some risk of collapse, due to problems including, among other factors, overfishing, poor enforcement, foreign poaching and under-reporting of catches. This paper examines and analyzes the problems relating to management of the conch fishery and speculates on its future. The main problems are overfishing by licensed fishers who take more than permitted, and serious poaching by industrial vessels mainly from Honduras, which exploit poor high seas enforcement by Jamaican authorities. For nearly two years the official fishery was closed due to legal issues. During closures, considerable foreign poaching occurred. The paper suggests that increased roles for the coast guard, continued quota reductions, and the Convention on International Trade in Endangered Species of Fauna and Flora (CITES), could be the best options for sustainability.

Inducing relaxation in the queen conch *Strombus gigas* (L.) for cultured pearl production

H. Acosta-Salmón, M. Davis

Source: Aquaculture 262(1):73–77. February 2007.

Five potential relaxant chemicals were evaluated: 2-phenoxyethanol, menthol crystals, benzocaine, MS-222, and magnesium chloride to induce relaxation in the queen conch for cultured pearl production. *S. gigas* were exposed to each chemical and were observed continuously for 30 min. Conch were placed on the bottom of the container with the aperture facing upwards (i.e., in an inverted position). When conch returned to their 'normal' position, they were turned facing upwards again. This process continued until conch were unable to return to their normal position. Only 30 g L^{-1} magnesium chloride induced adequate relaxation in *S. gigas* to attempt pearl seeding. Conch exposed to all other treatments, except 0.25 g L^{-1} menthol, showed a strong 'kicking' (escape) reaction during the initial 2 min to 7 min of exposure. After such reaction, conch retracted into their shells and within the 30 min exposure period they showed no signs of relaxation. Conch exposed to 0.25 g L^{-1} menthol did not attempt to right but slowly retracted into their shells and did not show signs of relaxation. Conch can be relaxed in 20 min with magnesium chloride. They showed an extended mantle, a relaxed foot and a slow response to physical manipulation.

Distribution, density, and abundance of the queen conch, *Strombus gigas*, in Los Roques Archipelago National Park, Venezuela

D. Schweizer, J.M. Posada

Source: Bulletin of Marine Science 79(2):243–257. September 2006.

Due to decades-long high levels of exploitation, in 1991 Venezuela closed the fishing of queen conch, *Strombus gigas* (Linnaeus, 1758). A visual assessment was carried out between July and September 1999 providing the most current data on distribution, density, and abundance of queen conch for Los Roques Archipelago National park. The assessment involved two random surveys. The overall estimated mean density and abundance were 18. 8 conchs ha^{-1} (SD = 44.5), and 1,374,640 conchs (95% bootstrapped C.L.: 640,474–2,023,897) for the 73,197 ha of the platform, < 40 m depth. Overall density values were close to those obtained in overfished areas of Belize and St. Thomas/St. John, U.S. Virgin Islands. The survey revealed zones with potential nursery areas and the largest aggregations of adults on sand plains at depths > 16 m, actively mating. Given the relatively low densities found, the susceptibility of the species to overfishing, the current economic alternatives in the area, the precarious enforcement of fishing regulations, and the presence of important breeding aggregations, we recommend that Los Roques Archipelago be kept as a sanctuary for this species, thus prohibiting the re-opening of the fishery.

Growth and mortality of Mediterranean mussel *Mytilus galloprovincialis* Lam., 1819, in relation to size on longline in Mersin Bay, Izmir (Turkey – Aegean Sea)

A. Lök, S. Acarli, S. Serdar, A. Köse, H. Yildiz

Source: Aquaculture Research 38(8):819–826. June 2007.

The growth and mortality rate of different size of mussels, *Mytilus galloprovincialis*, were compared in Mersin Bay, Izmir. Mussel sampling was performed on a monthly basis over 1 year, together with hyrobiological parameters. Water temperature, salinity, chlorophyll *a*, total particulate matter (TPM) and particulate organic carbon (POC) were determined. Average chlorophyll *a*, TPM and POC values were 3.88 ± 1.62 µg L^{-1}, 13.12 ± 3.68 mg L^{-1} and 252 ± 121.89 µg L^{-1} respectively. Initial mean lengths of mussels for each size group were 10 mm (9.91 ± 0.25 mm), 20 mm (20.14 ± 0.29 mm), 30 mm (30.66 ± 0.21 mm), 40 mm (40.14 ± 0.21 mm), 50 mm (50.62 ± 0.21 mm), 60 mm (59.77 ± 0.21 mm) and 70 mm (69.47 ± 0.62 mm). Maximum growth in length occurred during the spring–summer months. The annual length increments of mussel size groups were 46.22, 41.42, 30.3, 28.03, 20.63, 16.34 and 12.03 mm from small to large size groups respectively. Small

mussels grew faster than large mussels and reached commercial size at the same time. Mortality was <5% for all groups at the end of the experiment.

Spawning induction and early development of the Caribbean scallops *Argopecten nucleus* and *Nodipecten nodosus*

L.A. Velasco, J. Barros, E. Acosta

Source: Aquaculture 266(1–4):153–165. June 2007.

Argopecten nucleus and *Nodipecten nodosus* are two commercially valuable bivalve species from the Caribbean region, and are interesting candidates for mass culture in the sea based on laboratory production of juvenile "spat" organisms. An experiment of artificial spawning was performed with the two species as the initial part of a study on the feasibility of producing their spat. Stimulation of spawning was carried out, determining the percentages of individuals spawning, response time, numbers of gametes produced, and fertilization of the oocytes. Five external stimuli and eight combinations of those were tested: slow changes in temperature (ST), fast changes in temperature (FT), desiccation (*D*), high concentrations of microalgae (*M*), exposure to water currents (*C*), ST + *D*, ST + *M*, ST + *C*, FT + *D*, FT + *M*, FT + *C*, *D* + *M* and *D* + *C*. Four internal stimuli were applied, including intragonadal injection of serotonin (Se), dopamine (Da), Da + prostaglandin E_2 (Da + PE_2) and Se + PE_2. The results showed that *A. nucleus* spawned in response to all 17 stimuli tested, while *N. nodosus* responded to only eight of these (47%), suggesting that spawning in the first species was more sensitive to both external and internal stimuli. Larger percentages of individuals of *A. nucleus* spawned, with specially high values (100%) obtained with the ST + *M*, ST + *D* and Da stimuli; in *N. nodosus*, the Da stimulus was the most effective. *N. nodosus* gave shorter response times to stimuli than *A. nucleus*, with the shortest times in both scallop species (16 to 32 min) obtained using the internal stimuli. The production of gametes was similar between the two species, with about 5×10^9 spermatozoa, and 1.9×10^6 oocytes released per individual. *A. nucleus* produced higher numbers of spermatozoa using the ST + *M* stimulus, and higher numbers of oocytes using the FT + *M*, ST + *D* and Se stimuli; these values did not differ among treatments in *N. nodosus*. Abnormal spawning was observed in some of the internal stimuli tested, including release of immature gametes, simultaneous release of both male and female gametes, or sole production of male gametes. Fertilization was about 63% for both species, and was not influenced by the type of stimulation used to obtain the gametes. In summary, the most efficient stimuli for inducing the normal spawning of viable gametes in *A. nucleus* were ST + *M* and ST + *D*, and Se + PE_2 in *N. nodosus*. Early embryonic and larval development in *A. nucleus* were significantly more rapid than in *N. nodosus*, while the sizes of early embryos and larvae were similar in both species, and comparable to previous descriptions of scallops' early development.

Seasonal variation in weight and biochemical composition of the Pacific oyster, *Crassostrea gigas* in relation to the gametogenic cycle and environmental conditions of the Bizert lagoon, Tunisia

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Source: Aquaculture 263(1–4):238–248. March 2007.

Seasonal variations in biochemical composition of the bivalve *Crassostrea gigas* were studied from February 2002 until January 2003 in the Bizert lagoon in relation to environmental conditions and reproductive events. Separate analyses were made of gonad-visceral mass. The gametogenic cycle comprised tow phases: gametogenesis including ripeness and spawning (March–September) and sexual repose during the rest of the year. The *C. gigas* in the Bizert lagoon showed a clear cycle of energy storage and utilization. Total biochemical composition was about 6.50% ± 3.01 of dry weight in glycogen, 14.34% ± 3.60 of dry weight in protein and 6.67% ± 1.34 of dry weight in lipids. Lipid and glycogen concentrations in the gonad-visceral mass were inversely related: maximum concentrations of glycogen occurred between December and February and corresponded with minimum concentrations of lipids. High glycogen contents recorded in winter supported the processes of gametogenesis and then decreased progressively to attain low values at maturity and during summer corresponded to the first emission of gametes (June) and the beginning of total spawning, however lipids are accumulated in gonads during the period of maximum ripeness (spring) and decrease in summer. During autumn, the increase of total fatty acids values appeared to be related to the available food in association with an increase in the chlorophyll *a* concentrations. Protein contents show many variations throughout the year. High protein levels occurred in May and in July, which corresponded to oocyte maturation and then decreased in late summer (beginning of total spawning). At the expense of the available food in autumn, protein concentrations increase again to assure recovery of the tissue weight of the bivalve, which induced an increase in the condition indices values.

Density-dependent mortality of the scallop *Chlamys farreri* (Jones & Preston) in grow-out culture

X. Zhang, M. Zhu, R. Li, Z. Wang, L. Zhang

Source: Aquaculture Research 37(8):842–844. June 2006.

No Abstract.

Problems associated with shellfish farming

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Source: Revue scientifique et technique - Office international des épizooties 25(2):627–635. 2006.

Shellfish culture is a major sector of aquaculture production worldwide, and zoonoses and drug residues associated with shellfish farm practice are of concern to public health. This paper focuses on three of the most important shellfish species: molluscs, crabs and shrimp. Although many diseases can affect shellfish, they do not appear to be transmittable to humans. Rather, the main hazards are associated with the methods used to farm the different species. The risk to human health from shellfish most commonly relates to contamination by biotoxins produced by marine algae. Another well-recognised problem associated with shellfish culture is the contamination of shellfish with domestic sewage that contains human pathogenic bacteria and viruses, which causes diseases such as typhoid fever and hepatitis. In shrimp farming, the main potential food safety hazards are zoonoses, chemical contamination and veterinary drug residues. Untreated effluent from shrimp farms is a major concern to the environmental sector as it is known to promote plankton blooms if directly discharged into natural water sources.

Use of single cell detritus (SCD) produced from *Laminaria saccharina* in the feeding of the clam Ruditapes decussatus (Linnaeus, 1758)

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Source: Aquaculture 266(1–4):211–218. June 2007.

This study analyses the food value for bivalve mollusc seed of single cell detritus (SCD) from *Laminaria saccharina*, produced in accordance with the technique developed by Pérez Camacho et al. [Pérez Camacho A., Salinas J.M., Fuertes C., Delgado M., 2005. Preparation of single cell detritus from *L. saccharina* as a hatchery diet for bivalve mollusks. Mar. Biotechnol. 6, 642–649], which is based on the sequential action of two enzymes: endoglucanases and cellulases and two bacteria isolated in our laboratories: CECT 5255 and CECT 5256, which have high cellobiosic, proteolytic and alginolytic activities. Using this technique, *L. saccharina* meal is transformed in a suspension of algal cells and detritus of less than 20 μm in diameter, which can easily be filtered and digested by the bivalve molluscs.

SCD from *L. saccharina* can replace between 80% and 90% of the live phytoplankton content in the feeding of *R. decussatus*, with growth rates equalling, and even surpassing, those resulting from live phytoplankton diets. If we then factor in the low sedimentation of this product, the lack of proliferation of pathogenic bacteria in the culture vessels (possibly as a consequence of the control exercised by the bacteria used in the SCE production process), and the high survival rates of the individuals used in our experiments, we can well conclude that SCD from *L. saccharina* is an effective complement to live phytoplankton diets for *R. decussatus*, its use reducing the need to produce phytoplankton in industrial bivalve mollusc hatcheries by up to 90%. Similarly, the introduction of this food would also appreciably diminish operating costs in this kind of industry, where phytoplankton culture accounts for some 30% of total production costs.

Experimental trials on the feasibility of offshore seed production of the mussel *Mytilus edulis* in the German Bight: installation, technical requirements and environmental conditions

B.H. Buck

Source: Helgoland Marine Research 61(2):87–101. June 2007.

This study summarizes the activities and findings during a 2-year investigation on the grow-out of blue mussels (*Mytilus edulis*) and the technical requirements to withstand harsh weather conditions at an offshore location. The experimental sites were two different test areas, each 5 ha in size, 12–15 m in depth, in the vicinity of the offshore lighthouse "Roter Sand" located 15–17 nautical miles northwest of the city of Bremerhaven (Germany). Two versions of submerged longline systems were deployed: a conventional polypropylene longline in 2002 as well as a steel hawser longline in 2003, both featuring different versions of buoyancy modes. The spat collectors and grow-out ropes were suspended perpendicular from the horizontal longline for several months beginning in March of each respective year. The test sites were visited and sampled on a monthly basis using research vessels. Larval abundances in the surrounding water column

reached numbers of up to 1,467 individuals m^{-3}. Post-larval settlement success varied through the entire experimental period, ranging from 29 to 796 individuals of spat per meter of collector. Settled mussels reached a shell length of up to 28 mm 6 months after settlement. Based on the growth rates observed for the seed, it is projected that mussels would reach market size (50 mm) in 12–15 months post settlement, and at the observed densities, each meter of collector rope could yield 10.9 kg of harvestable mussels. The polypropylene line resisted storm conditions with wind waves of up to 6.4 m and current velocities of 1.52 m s^{-1} and was retrieved in autumn of 2002. In contrast, the steel hawser-based line did not withstand the harsh weather conditions. The steel-based line consisted of six twisted strands that were untwisted by the strong currents and turbulences and consequently the individual strands were torn. Additionally, the line was accidentally cut by a yacht in July 2003. The biological study revealed that the tested location near "Roter Sand" has the potential to become an offshore seed production site as well as being exploitable as a grow-out site for mussel production to market size. In light of the technical results, recommendations for mussel culture strategies using a polypropylene longline system are given.

Preliminary assessment of the potential for mangrove oyster cultivation in Piraquêaçu river estuary (Aracruz, ES)

L. Alvarenga, R.C. Nalesso

Source: Brazilian Archives of Biology and Technology 49(1):163–169. January 2006.

At Piraquêaçu river estuary, Aracruz, ES, the technical viability of *Crassostrea rhizophorae* cultivation was determined through monthly measures in shell length and weight. Seeds of *C. rhizophorae* were put in cages and suspended in rafts. Increase in height and weight (flesh and dry) of the oysters was measured. During ten months (July 98 to May 99), oyster shell reached an average of 37.6 mm in shell height and 3.0 g in flesh weight (the whole animal). High mortality rates were registered and could be related to the high salinity water and to high predation observed, especially by flatworms *Stylochophana divae* and snails *Cymatium parthenopeum*, as well as fouling organisms such as barnacles, Serpulidae polychaetes and seed of the same species.

Growth rate estimation of *Hexaplex (trunculariopsis) trunculus* (Gastropoda: Muricidae) based on mark/recapture experiments in the Ria Formosa lagoon (Algarve coast, southern Portugal)

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Source: Journal of Shellfish Research 25(1):249–256. April 2006.

This study reports growth rates estimates for *Hexaplex (Trunculariopsis) trunculus* (Gastropoda: Muricidae) from mark/recapture experiments carried out in the Ria Formosa lagoon (Algarve coast, southern Portugal). A total of 726 specimens (shell length and total weight ranging between 20.65–58.36 mm and 0.86–19.89 g, respectively) were marked with Dymo tape tags and released into a fish culture earth pond. During the marking process, no adverse effects on the whelks' health and behavior or immediate postmarking mortality were detected. Periodical recapture operations were undertaken using a traditional fishing gear designated locally as "wallet-line" and by hand gathering by scuba divers. A total of 170 whelks were caught, with a total of 216 recaptures (shell length and total weight ranging between 36.22–65.97 mm and 4.42–27.35 g, respectively), thus corresponding to a recapture rate of 29.8%. Despite the loss of one tag, all remaining tags were intact and easily readable. Marked individuals presented low monthly growth rates, in terms of shell length (1.0 mm month^{-1} or 2.3% month^{-1}), shell perimeter (2.0 mm month^{-1} or 3.1% month^{-1}) and total weight (0.7 g month^{-1} or 10.8% month^{-1}), which were highly variable between individuals and higher in smaller specimens. Data were used to estimate the von Bertalanffy growth parameters (length and weight) (K = 0.41, L_∞ = 82.76, W_∞ = 49.97 and t_0 = 0.05). The growth rate of *T. trunculus* was compared with results obtained in similar studies with other gastropod species to evaluate its potential for molluscan aquaculture.

Mechanical properties and structure of *Strombus gigas*, *Tridacna gigas*, and *Haliotis rufescens* sea shells: A comparative study

A.Y.M. Lin, M.A. Meyers, K.S. Vecchio

Source: Materials Science & Engineering C 26(8):1380–1389. 2006.

Sea shells are composed of calcium carbonate crystals interleaved with layers of viscoelastic proteins, having dense, tailored structures that yield excellent mechanical properties. Shells such as conch (*Strombus gigas*), giant clam (*Tridacna gigas*), and red abalone (*Haliotis rufescens*) have hierarchical architectures that differ depending on growth requirements and shell formation of the particular mollusk. Mechanical tests have been carried out on these shells for a comparison of strength with respect to the microstructural architecture

and sample orientation. The mechanical response is found to vary significantly from specimen to specimen and requires the application of Weibull statistics in order to be quantitatively evaluated. The complex micro-laminate structure of these biocomposite materials is characterized and related to their mechanical properties. The red abalone has the highest compressive (233–540 MPa) and flexure strengths of the three shells. The giant clam has the lowest strength (87–123 MPa) and the conch has an intermediate value (166–218 MPa) in compression. The high compressive strength observed in the abalone is attributed to an optimization of microstructural architecture in the form of 2-D laminates, enhancing the fracture toughness of this shell material and enabling higher stresses to develop before fracture.

Reproductive cycle of the purple snail *Plicopurpura pansa* (Gould 1853) from two locations at Baja California Sur, Mexico

L.C.A. Naegel, F.A. García-Domínguez

Source: Journal of Shellfish Research 25(3):925–933. December 2006.

The reproductive cycle of purple snail, *Plicopurpura pansa* (Gould 1853), sampled randomly monthly over a period of 20 months at Playa Cerritos at the Pacific, and Punta Perico at the Gulf of California, Baja California Sur, Mexico, was examined by histological observations of the gonadal development. At both sites year-round copulations were observed, whereas egg capsules could be found only during February to May. During nearly the whole period, male and female gonads were found in the developing stage. From January to July and August most female gonads were found in the ripe, and from January to June and August in the spawning stage. Male gonads in the spawning stage were observed from December to September. The recovering stage was found in male and female gonads between September and October. Synchronism of gonadal development between both sexes was evident. Spawning could be observed in females with a total shell length of more than 18 mm, whereas smaller animals had gonads in the developing stage. In gonads of males signs of spawning could be observed in animals larger than 18 mm. No relationship was found between the water temperature and the spawning period. The sex ratio was 1:1 at Playa Cerritos, whereas at Punta Perico more males than females were counted.

Molluscan natural products as biological models: chemical ecology, histology and laboratory culture

C. Avila

Source: Molluscs. G. Cimino, M. Gavagnin (Eds.), Springer-Verlag Berlin Heidelberg 2006

The utility of some natural products from molluscs has been known for centuries. However, only recently have modern technologies and advances in the fields of chemistry, chemical ecology, anatomy, histology, and laboratory culture allowed the exploitation of new, unprecedented applications of natural products. Recent studies have dealt with (a) the role that these compounds have in the sea in protecting the animals (e.g., chemical defense), or in mediating their intraspecific communication (e.g., pheromones), (b) the geographical differences in similar or related species (and the implications of this in chemical ecology and phylogeny), and (c) the localization of these metabolites in molluscan tissues (by means of the most modern technologies), among others. The methodology for the laboratory culture of some species has also been established, thus offering new insights into this interesting field. Further applications of all these challenging studies are currently being developed.

Endocrine disruption in prosobranch molluscs: evidence and ecological relevance

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Source: Ecotoxicology 16(1):29–43. February 2007.

Prosobranch snails represent almost 50% of all recent molluscs, are ubiquitously distributed, play important roles in various ecosystems and exhibit a variety of reproductive modes and life-cycle-strategies. Many of them attain life spans of several years, which in combination with their limited ability to metabolize organic chemicals, may contribute to the fact that prosobranchs constitute one of the most endangered taxonomic groups in aquatic ecosystems. Although it is not yet known to what extent endocrine disrupting chemicals (EDCs) contribute to this situation, the case of tributyltin (TBT) and its population-level impact on prosobranchs demonstrates the general susceptibility of these invertebrates. The existing evidence for comparable population-level effects in prosobranch snails by other androgens, antiandrogens, and estrogens is critically reviewed. The example of TBT demonstrates the difficulty to prove an endocrine mode of action for a given chemical. Although it is generally accepted that TBT causes imposex and intersex in prosobranch snails as a result of endocrine disruption, the detailed biochemical mechanism is still a matter of debate.

The strengths and weaknesses of the five competing hypotheses are discussed, together with previously unpublished data. Finally, the ecological relevance of EDC effects on the population and community level and the application of prosobranchs for the assessment of EDCs are addressed.

Sex and genetic structure across age groups in populations of the European marine invasive mollusc, *Crepidula fornicata* L. (Gastropoda)

L. Dupont, D. Bernas, F. Viard

Source: Biological Journal of the Linnean Society 90(2):365–374. February 2007.

In long-lived species, variance in allele frequencies over time may vary according to the number of generations contributing to progeny. Here, we investigate the temporal stability of genetic diversity and structure in relation to sex and age in introduced populations of *Crepidula fornicata*, an exotic gastropod that successfully invaded Europe. This protandrous species has the potential to change sex from male to female according not only to age, but also to local sex ratio (social environment). This mechanism may adjust the reproduction efficiency across different cohorts and thus decrease the likelihood of genetic drift in the following generations. Based on crude demographic structure analysis in two spatially closed introduced French populations, we demonstrate that recruitment is discontinuous. Although timing of sex change is different across populations, both populations have a similar age structure characterized by distributions of males and females changing across generations. Using five microsatellite loci, we show that both populations display a temporal genetic homogeneity and a stability in genetic diversity indices across age groups examined. Our results highlight that the social control of sex change in *C. fornicata* has strong implications to the maintenance of high genetic diversity by enhancing breeding across several generations at each reproductive season.

Biology and fishery of the whelk *Buccinanops globulosum* (Kiener, 1834) in northern coastal waters of the San Matías Gulf (Patagonia, Argentina)

M.A. Navarte

Source: Fisheries Research 77(2):131–137. 2006.

The whelk *Buccinanops globulosum*, a very common prosobranch mollusk in northern Patagonian, is the target of a new fishery in San Matías Gulf. Given certain biological characteristics making this species susceptible to overfishing, a study started in 2000 in order to collect data on demography and growth at age of this species, with the aim to design and to implement a provisional management plan. Mean density was estimated at 111 individuals m^{-2} (S.D. = 16.77). Females outnumbered males in most of the months (P<0.05) and appeared laying egg capsules from November to January. The smallest female carrying egg capsules was 45.2 mm total conch length (n = 36). Recruitment peak was identified in January 2002 and January–February 2003. Early crawling juveniles had a mean size of 4.2 mm conch length (S.D. = 0.51, n = 60). A total of 450 individuals (263 females and 187 males) were examined for growth at age. Significant differences were found in the growth parameters between sexes (maximum likelihood method; X = 92.34; g1 = 3; P< 0.001). Growth of males was lower than growth of females. Commercial capture of whelks is done by diving using a bait of fish discarded or open living purple clams. Only adults up 4 cm are retained during the fishing operations in a net bag. During 2000–2004 the annual catch varied from 20 to 9200 kg. Fluctuations in landings have more often reflected market prices rather than changes in the abundance of the resource. If effort for this whelk increases it should be necessary to consider a period of no fishery at all in the reproductive/recruitment period in order to ensure the sustainability of the stock.

Site- and species-specific distribution patterns of molluscs at five intertidal soft-sediment areas in northwest Europe during a single winter

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Source: Marine Biology 151(2):577–594. April 2007.

In this study we aim to provide a basic description and comparison of the spatial distribution and population structure of the common intertidal mollusc species, sampled within a single winter along a latitudinal gradient of different soft-sediment areas spanning 8° of latitude (46°–54°N) and 900 km of distance in northwest Europe. Sediment samples were collected from December 2003 to early March 2004 in the Wadden Sea (The Netherlands), the Wash (United Kingdom), Mont Saint–Michel Bay (France) and two bays on the central French Atlantic coast in south of Brittany. Core-sampling over 250 m grids allowed us to cover 3–30 km² at nine separate intertidal subsites, with a grand total of 2,103 points visited. Among the 15 bivalve and 8 gastropod species collected, we focused on the four most common and abundant bivalve

species (*Cerastoderma edule*, *Macoma balthica*, *Scrobicularia plana* and *Abra tenuis*) that together represented 96% of all collected bivalves, and on the mudsnail *Hydrobia ulvae* that comprised 99% of all collected gastropods. *C. edule* and *M. balthica* were the most widespread bivalves, with higher densities occurring at higher latitudes. *S. plana* and *A. tenuis* were more abundant at southern sites, both with a clear preference for muddy sediments. The mudsnail *H. ulvae* occurred commonly and in comparable densities at all study sites, except in Mont Saint–Michel Bay where it was very rare. Mean sizes of the common molluscs were highly variable between sites, without clear north–south gradients. The mollusc distribution patterns at the five intertidal areas and nine subsites were predominantly site-specific. Mollusc community composition showed greater similarity within than between the regions north and south of the Brittany peninsula.

Seasonal variations of immune parameters in diploid and triploid Pacific oysters, *Crassostrea gigas* (Thunberg)

M.B. Duchemin, M. Fournier, M. Auffret

Source: Aquaculture 264(1–4):73–81. April 2007.

During the last two decades, knowledge of shellfish immunology has been largely improved and the immune status of bivalves can be assessed by the measurement of both cellular and humoral parameters. Previous monitoring studies in which the immune status of bivalve molluscs has been assessed have demonstrated that many parameters may vary greatly among sites and seasons, suggesting that environmental and endogenous factors may affect this system. Reproduction may also interfere with the immune system. This study focuses on the seasonal variations of the immune parameters in two batches of Pacific oysters differing by their ploidy, diploid's and triploid's. The oysters were sampled from a French oyster farm over two reproductive periods. Selected immune parameters investigating haemocyte integrity and immunocompetency were analysed monthly by flow cytometry. Histological observations were made in gonads to discriminate gender and gametogenesis stages. Results indicate that immune parameters in both diploid and triploid oysters exhibited marked seasonal variations. Phagocytosis index was significantly low during spawning before reaching a maximum in autumn. Triploids also appeared to be less sensitive to environmental cues than diploids. Taken as a whole, alterations observed in maturing individuals corresponded to a depressed immune status in late spring, at a time corresponding to the spawning period. Furthermore, grouping by sex of ongoing gametogenesis individuals revealed uneven immune alterations among males and females. Finally, grouping sexual maturation stages showed evidence of a peculiar stressful event during early gametogenesis, perhaps under endogenous control.

Mussels flexing their muscles: a new method for quantifying bivalve behaviour

A. Robson, R. Wilson, C. Garcia de Leaniz

Source: Marine Biology 151(3):1195–1204. May 2007.

We employed a novel technique to quantify how blue mussels *Mytilus edulis* react to predation risk in their environment by quantifying mussel gape using a Hall sensor attached to one shell valve reacting to a magnet attached to the other. Change in gape angle per second (CHIGA) versus gape angle plots resulted in a distribution with a boundary, which defined the maximum CHIGA of a mussel at all gape angles. CHIGA boundary plots for all individual mussels were similar in form. However, the CHIGA boundary increased in extent with mussel length (maximum CHIGA for mussel valve closures for mussels 2.98 and 79.6 mm long were -1.5 and $-11° s^{-1}$, respectively), showing that larger mussels opened and closed most rapidly. Mussel extract added to the seawater, a factor believed to signal predation, caused mussels to close significantly faster than otherwise ($P < 0.001$). This approach for assessing how mussels react to their environment indicates that mussel response to predation is graded and complex and may well indicate animal-based assessments of the trade-off between effective feeding and the likelihood of predation.

Isolation and characterization of eight polymorphic microsatellite markers from pink conch (*Strombus gigas*)

R. Zamora-Bustillos, R. Rodríguez-Canul, F.J. García De León

Source: Molecular Ecology Notes. 2007. doi: 10.1111/j.1471-8286.2007.01687.x

Many marine organisms have pelagic larvae, and these are often important agents of dispersal. The larval phase and the multiple paternity that occur in marine gastropods such as *Strombus gigas* are crucial for the success of this species throughout the Caribbean Sea. To analyse these factors, we developed eight microsatellite loci specific to *S. gigas*. On the same set of individuals, the microsatellite loci exhibited a greater level of polymorphism than previously studied allozyme markers and thus, will permit fine-scale analysis and larval pool studies.

Mechanism of a plastic phenotypic response: predator-induced shell thickening in the intertidal gastropod *Littorina obtusata*

J. I. Brookes, R. Rochette

Phenotypic plasticity has been the object of considerable interest over the past several decades, but in few cases are mechanisms underlying plastic responses well understood. For example, it is unclear whether predator-induced changes in gastropod shell morphology represent an active physiological response or a by-product of reduced feeding. We address this question by manipulating feeding and growth of intertidal snails, *Littorina obtusata*, using two approaches: (i) exposure to predation cues from green crabs *Carcinus maenas* and (ii) reduced food availability, and quantifying growth in shell length, shell mass, and body mass, as well as production of faecal material and shell micro-structural characteristics (mineralogy and organic fraction) after 96 days. We demonstrate that *L. obtusata* actively increases calcification rate in response to predation threat, and that this response entails energetic and developmental costs. That this induced response is not strictly tied to the animal's behaviour should enhance its evolutionary potential.

Bivalve genomics

C. Saavedra and E. Bachère

Interest in bivalve genomics has emerged during the last decade, owing to the importance of these organisms in aquaculture and fisheries and to their role in marine environmental science. Knowledge of bivalve genome structure, function and evolution resulting from 20th century "single gene" approaches is limited, but genomic technologies are called to dramatically increase it. Research based on linkage maps, transcriptomics and proteomics is being carried out to study the genetic and molecular bases of traits of interest in bivalve farming industry, mainly disease susceptibility, tolerance to environmental stress, and growth. The Pacific oyster (*Crassostrea gigas*) is now the focus of an international genome-sequencing consortium. The use of bivalves in pollution monitoring has prompted the genomic study of the cell and organism responses to xenobiotics, which should expand into the field of phytoplankton toxins. Future work should also pay more attention to the larval stages, and to basic processes such as growth, sex-determination, and gonad development.