The perilous lifecycle of Haliotis iris:

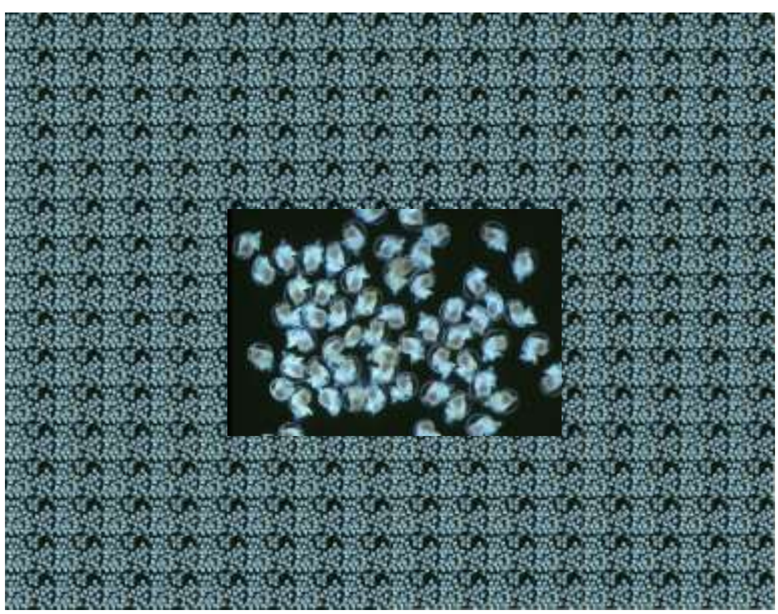
from the miracles of fertilization and metamorphosis through to the Russian roulette game of growing up

Ellie Watts

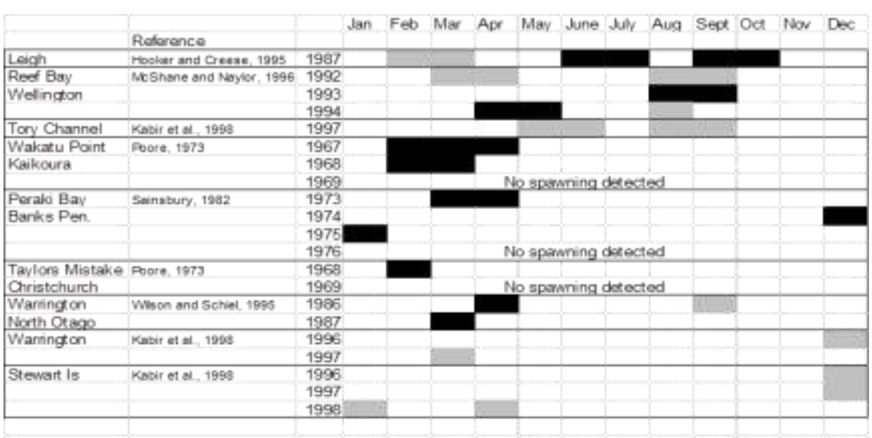
High-end reef real estate

Born to spawn

- Potential to release several million eggs per year
- Lifespan 20+ years
- One adult female could spawn 80 to 200 million eggs over her lifetime



Natural spawning periods of H. iris

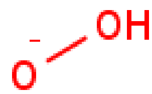


From chopping up lots of gonads we know…

- paua become sexually mature ~4 to 5 years
- paua have high fecundity which increases with size = lousy offspring survival rates
- they have irregular spawning patterns which make for very untidy graphs

Adult paua require lots of good tucker and stable sea temps for healthy gamete production

The chemical equation of love



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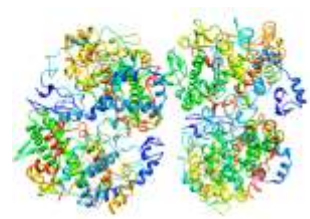

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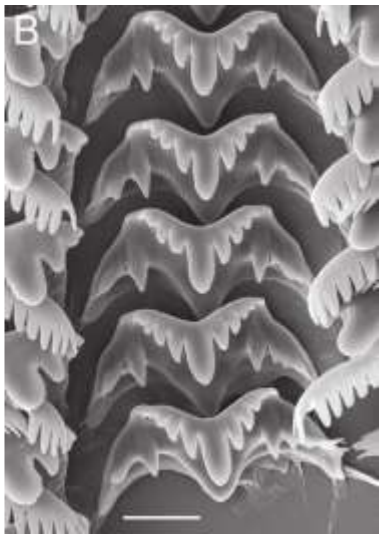
Paua aggregations : an increasingly rare phenomenon

Trochophore larva 22hrs post fert

Veliger larva; torsion is just for gastropods


Filter feeders are not friends

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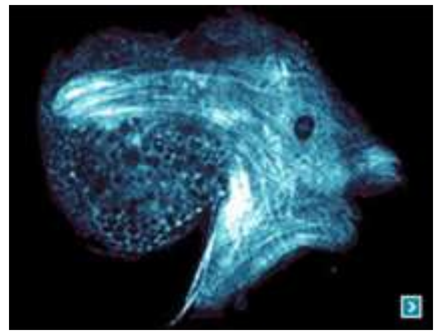

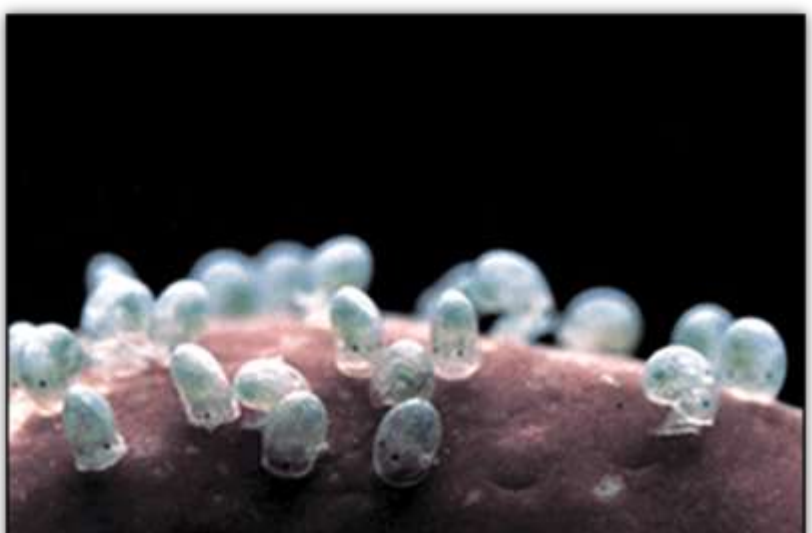

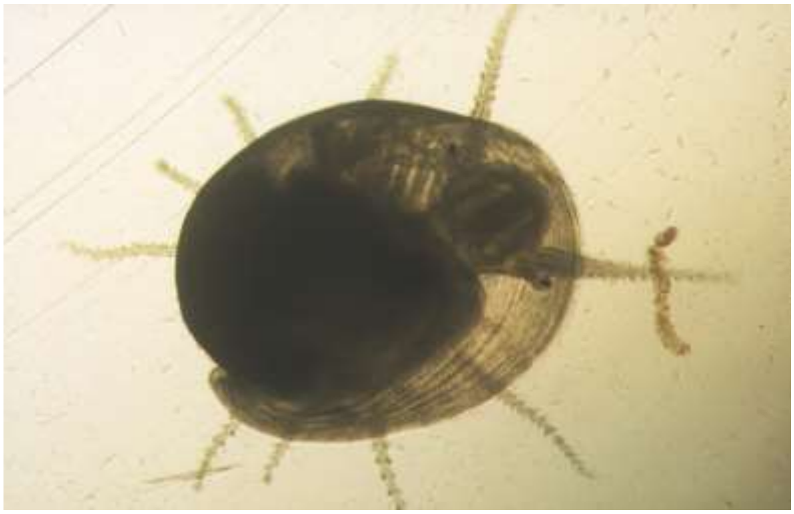

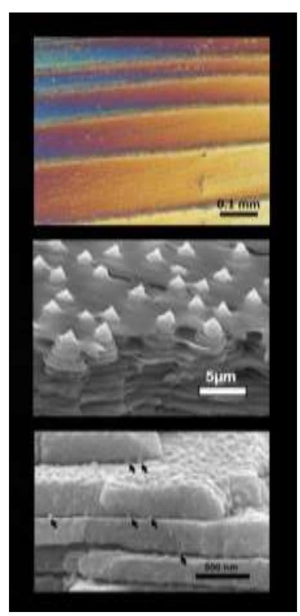
0.1 mm
5µm

Predators of post-larvae

School of hard knocks




Not nice neighbours




Things that make life extra hard

When you're chewing on life's gristle
Don't grumble, give a whistle
And this'll help things turn out for the best.
And...always look on the bright side of life.
Always look on the light side of life.
- Monty Python's Life of Brian

CAWTHRON INSTITUTE

The Life of Brian: the perilous lifecycle of paua. An overview of H. iris from the miracles of fertilization and metamorphosis through to the Russian roulette game of reaching adulthood.

Ellie Watts – Cawthron Institute

The paua shell I'm holding here represents something quite remarkable; Brian the paua, before he selflessly gave his body to science after an unfortunate accident involving a truckload of rat poison, actually reached adulthood and beyond in the wild – a feat that was quite possibly one in approximately 20 million.

We're going to go over some old ground and reintroduce ourselves to the perilous life cycle of the humble paua, covering some areas we think we know quite well but also touching on contestable areas of mystery and supposition. Keep in mind this talk focuses on Brian's very fortunate lifespan, where he was born into a highly sought after area of reef real estate south of Kaikoura, and where the pitfalls of anthropomorphic influences have been minimal – except perhaps for the rat poison incident.

Let's take a stab at healthy adult female's lifetime of spawning; once reaching the rather tender age of 4 or 5 years, she along with her male counterparts would begin to produce gametes. If the planets aligned and she actually spawned, she could potentially release a couple of million eggs per year. Perhaps double that. If she lived for 20 years, which is very achievable, she could produce something in the order of 80 million eggs. Perhaps 160 million if things went well, but let's stay on the conservative side. So if she belonged in stable population, two of her eggs would survive to adulthood.

Spawning and fertilization

For blackfoot paua in New Zealand's latitudinal spread of waters, spawning events are difficult to graph. The sites from these eight independent studies are arranged from the north at the top, to the south at the bottom. The black bars indicate definite spawning events, while the grey bars are possible minor spawnings. As you can see, events appear to loosely trend towards a drawn-out season from mid-winter, through to late spring in northern areas of the country where they typically grow more slowly and thus reach maturity at a smaller size. In the cooler, southern regions, mid-summer to the end of autumn are the more popular spawning months, with these paua generally growing faster, so they're bigger by the time they reach 5 or 6 years of age and they probably will have had less time in the water contributing to spawnings before reaching the legal size of 125mm, than their northern counterparts.

Spawning seasons are especially fickle for adults reaching sexual maturity. From limited studies carried out from chopping up gonads and looking at them closely, females around 90 mm in shell length can have tens of thousands of oocytes in different phases of maturation in their gonads, while paua around 130 mm+ have the capacity to hold several million.

Paua in the wild aren't all that disciplined about how they spawn. They can release most of the ripened gametes in a single spawning, or trickle a few out over a few days, spawn here and there over a few months, or even reabsorb them if conditions aren't quite right – this is an area involving complicated and changing exogenous and endogenous variables we really don't know that much about.

Leading up to Brian's rather immaculate conception, his 'mum and dad' would have needed to feast on up to 15% of their body weight in top-condition kelp per day, and required reasonably stable annual sea temperatures while converting most of their reserves into gametogenesis and biochemical ripening of these prized gametes.

Cue the mood: the big orgy day arrives – it more than likely followed a good old storm which forced cooler water upwellings in the area, potentially raising the levels of hydroperoxy free radicals in the sea, activating the hormone production of prostaglandin endoperoxide synthetase and triggering some members of the congregation of paua to blow their loads – or perhaps just trickle a bit out. Curiously enough, it seems that the precious gametes actually released require one final step in maturation and are squeezed through the right kidney before being effectively peed out into the gill chamber and puffed through the respiratory pores out into the wild blue, where they're on their own.

Brian's egg half could have been one of up to a couple million eggs released by that single female during that event – perhaps this was the only event of the year in that patch. These green spheres a quarter of a millimetre in diameter, would have wafted around in partial suspension, requiring a good dose of healthy sperm to be nearby. Trials in the lab have shown that less than 1000 sperm per mL directly around eggs results in very low fertilization rates, as does increasing egg age before contact with sperm. Ideally, a concentration of more than 25,000 sperm per mL are needed around eggs that are less than half an hour old to reach anything like 70% fertilization. Paua are basically into group sex: the bigger and tighter the orgy, the better. It can be a rather futile and lonely effort to puff out your gametes when your nearest spawning counterpart is many body lengths away.

Adult aggregation

Not much is known about adult aggregation behaviour leading up to spawning events – whether Haliotis iris actively do this or not, but even just appreciating difficulties surrounding events leading up to a spawning, let alone successful fertilization of some gametes should make us appreciate the importance of paua aggregations. Perhaps that little gut of 'stunted stock', crammed in like sardines is the perfect, possibly the only decent aggregation around for tens if not hundreds of metres? Perhaps they're the main source of the harvestable paua seen growing around nearby? Perhaps these populations are worth treating conservatively when it comes to projects such as translocation, where the stunted base population and shifted ones are both given the opportunity to 'grow into the fishery' – just to be taken in a year or so. If focus is starting to shift towards pockets of stunted stock, the wider fishery area potentially needs some careful management first.

Embryo development

So for Brian the developing embryo, if he was floating around in the 14 degree waters of Kaikoura in April for example, and all was good in the rare world of perfect marine chemistry, he would take around 22 hours to develop from a mass of dividing cells and emerge from the egg case as a very vulnerable trochophore larva - something resembling a weird little spinning top with an afro and the beginnings of a fragile, protective shell forming Another 24 hrs later, the larval shell formation complete, his entire insides would have undergone torsion – a 180 degree twist and flip characteristic of all gastropods. This tricky manoeuvre brings the mantle cavity and anus to a forward position above the head.

The cilia-framed flaps called the velum gives him a bit of locomotion and a trapdoor (the operculum) allows him to lock himself away in the fragile larval shell if things got a bit nasty – although bumping into an anemone or most filter feeders would have disastrous consequences

As a veliger larva, he'd come with a pre-packed lunch of lipids, proteins and amino acids in the yolk, along with a small and curious appetite for dissolved organic matter and begin developing rows of chitinous little teeth – in preparation for landing in around 7 to 10 days. Back in the lab, we can do a rather nasty little test called a radula squash to determine whether larvae are competent to settle. It involves a series of acid washes that dissolve the shell, then a bath in ethanol to dehydrate the tissues. The resulting mess, when sandwiched between glass slides, leave behind a beautifully intact radula, a pair of disturbing eyeballs and not much else. The art is then to count the rows of teeth formed. When the larvae have around five or more rows of teeth, they're deemed fit to settle – which is not the case for the unfortunate few under the scope. As adults they'll have more than 90 of teeth

Settlement/metamorphosis

In the best of worlds, Brian's short swimming phase with rather limited propulsion would keep him within the general vicinity of the adult group, preferably with a nice, stable bouldery habitat with plenty of corraline algae (pink paint pic)with lots of nooks and crannies to hide. The presence of crustose corraline algae and the stuff that grows on them play a critical role in the settlement and metamorphosis of paua larvae, with chemical cues in the form of amino acids primarily triggering this event. Over the course of a few days the larvae will test the substrate around them, picking up these vital chemical cues which lead to major physiological changes in the larvae; the velum supporting the tiny cilia basically beat themselves free and the operculum – the wee trap door, detaches as the foot becomes more mobile. Suddenly the larva is a proper, tiny crawling snail. The radula is put to good use for the first time, scraping off tiny particals of algae and bacteria into a brand new digestive system. Trials in the lab tanks have shown encourging grazing trails over biofilms of diatoms only to result in a starving and dying population. After culturing a post-larva's poo in a petri dish, intact diatoms have shown to pass right through the digestive system. So the radula has been strong enough to pick up the diatom, but not break the tough silica frustule for further digestion. Clearly, the first couple of weeks finding the right algae cells is critical.

After a couple of months, wee Brian would be around 2 to 3 millimetres long and would have developed his first respiratory pore. His spanking new shell is laid down by some rather remarkable cells situated on the mantle layer of tissue. Polymorphs of calcium carbonate form the rather horny outer calcite layer and the striking iridescent aragonite plates beneath. A fantastic proteinaceous and flexible glue of conchiolin binds the layers together to form a matrix that is 3000 times tougher than the individual shell components.

Even with such tough armour, anything with an appetite for things this small is a potential predator; polyclad flat worms, terebellids, anemonies, glycera worms.. a real frightening bunch of wee marine monsters. (pics of..) If the labours of metamorphosis were successful, here's where millions of post-larval buddies of Brian's would go no further.

Cryptic behaviour

Over the next four to five years the game is all about hide and seek; juvenile paua will creep towards shallower waters, remaining cryptic and mostly nocturnal – hiding in notches and crevices under and around bouldery habitat and keeping a very low profile while seeking out desirable algae and biofilms. They'll remain hidden until they reach around 60mm, depending on how fast they're growing and the nature of the reef they inhabit, until which stage they'll begin to emerge to stake out desirable spots for catching drift seaweed.

Storms can have disastrous effects on juvenile and adult populations. Especially where boulders and gravels can be picked up and move around, crushing and dislodging paua. A solid storm in Taranaki can bury large areas of solid volcanic reef under two metes of fine iron sand and smother the lot. Weather aside, not only are paua competing with every other grazer around them like kina, and other marine snails, but they're hot on the menu for anything that can fit in the same hiding places or are good ambush predators, such as crabs and triplefins, probing octopus and starfish tentacles, snapper, wrasse, and blue cod. Giant seven armed starfish can use the tip of an arm like a conveyor belt to squeeze into a small crevice and extract reseeded juvenile paua, supposedly safe from larger predators.

So when you step back and have a look at the wider picture, it really is quite amazing that paua make it at all, even when presented with an ideal world.

Some very clever research is being carried out now, examining shifts in marine carbonate chemistry, warming oceans and the multitude of pollution sources driving complicated environmental changes. Small shifts in pH and temperature, increasing levels of heavy metals, nutrient loading and particulate matter in the sea are all showing alarming trends of stacking the odds against abalone survival. Algae blooms are more prevalent, affecting light levels for kelp growth. Warming sea temperatures can effectively render some abalone sterile, drops in pH hinder larval shell development while copper alone has shown serious deleterious effects on the development of abalone larvae. Throw in some fishing pressure, either directly or indirectly via the harvesting of other target species, and this can heavily impact on their back yards, can alter their niche, drive them out or just make an area too hostile for living (kina barrens).

Abalone are our planet's most primitive group of molluscs. They haven't really changed that much in 500 million years. Maybe some abalone species have some remarkable tricks up their skirts with the ability to adapt to rapidly changing environments, or perhaps they don't. Regardless to say, it's a good idea to have a close nosey at our abalone's precarious life cycle – to take note, to marvel and appreciate the phenomenon of making it to adulthood.