Hatchery Manual for Black Jewfish (Protonibea diacanthus)

Darwin Aquaculture Centre

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Executive Summary

Black jewfish *Protonibea diacanthus* is a high-value sciaenid fish species with significant potential for aquaculture production in northern Australia. The species is highly regarded for its eating qualities but is especially prized for its collagen-rich swim bladder, which commands premium prices in international markets. Declining wild stocks and increasing fishing pressure have highlighted the need for alternative production methods to support industry development and reduce reliance on wild harvest.

Since 2018, the Darwin Aquaculture Centre (DAC) has undertaken research and development to establish reliable hatchery production techniques for black jewfish. This work has included broodstock collection and management, induced spawning, larval rearing, juvenile production, health management, and nursery culture. Through a collaboration between the Northern Territory Government, the Cooperative Research Centre for Developing Northern Australia (CRCNA), and industry partners, DAC has successfully produced multiple generations of black jewfish and generated the technical knowledge required to support future commercial production alongside continuing research.

The protocols presented in this manual represent the culmination of eight years of research and small-scale production undertaken at the DAC and reflect current best practice. The manual provides practical guidance on seawater treatment, broodstock husbandry, disease management, spawning induction, larval rearing, juvenile culture, handling techniques, and health monitoring. The manual is intended to serve as both an operational reference for hatchery personnel and a foundation for future industry development. While ongoing refinement of culture methods is essential, the techniques described have enabled the routine production of black jewfish fingerlings under Northern Territory conditions. The appendices provide supporting operational tools, including culture parameter guidelines, larval rearing schedules, health monitoring forms, treatment records, sedation protocols, and sexual maturation assessment and spawn induction templates.

Black jewfish possess several biological characteristics favourable for aquaculture, including rapid growth, potentially strong market demand, and adaptability to intensive larval culture protocols. However, several constraints continue to limit large-scale commercial production. The most significant challenges identified during hatchery development have been inconsistent broodstock reproductive performance and severe cannibalistic behaviour during the transition from late larval to early juvenile stages. Adult and sub-adult fish also appear quite susceptible to parasite mortalities. Together, these bottlenecks can substantially reduce egg quality, larval and juvenile survival, and overall fingerling production.

Continued research is required to improve spawning reliability, reduce juvenile cannibalism, optimise grow-out performance, and evaluate the economic potential of swim bladder production. Addressing these constraints will be critical to establishing black jewfish as a commercially viable aquaculture species and supporting the sustainable growth of a new aquaculture industry in northern Australia.

1. Introduction

1.1. Biology and Life History

The black jewfish *Protonibea diacanthus* is a large member of the family Sciaenidae, distributed throughout the Indo-West Pacific (Smart et al., 2025; Williams et al., 2023). In Australia, black jewfish occur along the northern coastline from Western Australia to Queensland inhabiting estuarine, coastal and nearshore marine and brackish water environments. Black jewfish are demersal fish and are found down to depths of 100 m in soft-substrate, tidal channels and reef habitats. They are opportunistic feeders, feeding mainly on small crustaceans and fishes (Barton 2018). The black jewfish supports valuable commercial fisheries throughout the Indo-West Pacific region, where it is harvested for both its flesh and highly valued swim bladder (Ben-Hasan., 2026).

Black jewfish are a fast-growing species with a long lifespan compared with other tropical fish. In Australia they have been reported to grow up to 150 cm and 40 kg in weight, with a maximum age of 15 years (Randall et al., 2023). In the wild 50 % of individuals are sexually mature once they reach 90cm in length, generally at two years of age (Smart et al., 2025). Reproduction occurs during large annual spawning aggregations, with fish returning to the same locations multiple times over their life to spawn (Phelan et al., 2008; Williams et al., 2023; Semmens et al., 2010). This predictable spawning behaviour makes the species particularly vulnerable to overfishing, as the timing and location of aggregations are reliable and readily exploited by fishers. Adult black jewfish are broadcast spawners and release their eggs and sperm into the water column where external fertilisation occurs (Taillebois et al., 2017).

Molecular studies on black jewfish have highlighted the complex genetic connectivity of the species in northern Australia. Taillebois et al. (2017) showed that across 11 sampling locations, from Roebuck Bay in WA through to the Vanderlin Islands in the Northern Territory (NT), there were four distinct genetic populations with limited gene flow between them. Additionally, Semmens et al. (2010) monitored tagged black jewfish across three known aggregation sites in the Greater Darwin region for 1.5 years and found that individuals were only recorded at their original aggregation site. The lack of gene flow and high site fidelity displayed by this species suggests individual populations face risks associated with localised depletions and reductions in genetic diversity.

1.2. Wild Fishery

A prized feature of the black jewfish is its large, collagen-rich swim bladder. The swim bladder holds significant value in Asian markets where it is dried and used as “maw” in soups for culinary and medicinal applications. Many species of sciaenid fishes are targeted for their flesh and swim bladders, and while prices can vary significantly, black jewfish swim bladders can sell for up to $139–2299 USD/kg wet weight depending on product quality, size and origin (Ben-Hasan, 2021). Commercially caught black jewfish swim bladder sale prices in the NT have varied widely. NT Fisheries data shows the average price of a high-quality swim bladder in the NT is $600 AUD in 2026, up from $350 in 2010. In 2024 high-quality individual black jewfish swim bladders were sold for an average of $960 (NTG DAF, 2026).

The high market value of the swim bladder and the species’ tendency to form predictable spawning aggregations have made the black jewfish vulnerable to overexploitation in many locations. Consequently, the black jewfish is currently classified as Near Threatened by the International Union for Conservation of Nature (IUCN) (Sadovy et al., 2020). Population declines have been recorded in India, West Papua, Hong Kong and Australia (Sadovy et al., 2020). In other countries across its distribution there is limited reporting and catch data available making stock assessments difficult and likely inaccurate. This further complicates the management of black jewfish fisheries, which already face challenges regarding hyperstability. Hyperstability denotes when the catch per unit effort, an important measure in stock assessments, remains

stable despite significant reductions in biomass. This pattern is common in species that form spawning aggregations as fish are more readily harvested when aggregated and catches are reported during aggregations and not at other stages of their life cycle. The high market value of sciaenid swim bladders has contributed to increased fishing pressure on a number of these species globally, leading to increased efforts to protect wild populations. The development of aquaculture for these species may provide a way to reduce overfishing of wild stocks while also offering a valuable product for commercial aquaculture.

In northern Australia, a decline in the black jewfish fishery was first reported in Cape York during the 1990's and in the Greater Darwin Region during the mid-2010's. These declines prompted an increased focus on enhancing the accuracy of stock assessments for this species. A recent assessment completed in the Northern Territory (NT) in 2023/24 reported that the black jewfish spawning biomass is approximately 41% of original unfished levels (Smart et al., 2025). This is a marked improvement from assessments in 2014 that reported biomass and egg production at only 28% of unfished levels and the concluded that the NT stock was being overfished (Saunders et al., 2014). Despite the stock recovery, concerns remain over the sustainability of the fishery into the future as demand for both black jewfish flesh and swim bladder products continue to rise.

1.3. Aquaculture

Several sciaenid species are cultivated globally and have proven to be excellent candidates for aquaculture production (Chaćon Guzman et al., 2025; Yang et al., 2025). These fish are fast growing, have good feed utilisation and feed conversion and high market value. The largest producers of farmed sciaenids are China, with an annual production of 270,000 tonnes of large yellow croaker *Larimichthys crocea* and 70,000 tonnes of red drum *Sciaenops ocellatus*, and Europe, with 60,000 tonnes of meagre *Argyrosomus regius* (EUMOFA, 2026; Xiao et al., 2023; Yang et al., 2025). Large yellow croaker and meagre aquaculture products now outstrip wild caught supply (EUMOFA, 2026; Chaćon Guzman et al., 2025). Despite the increasing uptake and focus on sciaenid aquaculture, challenges remain in this field with constraints regarding spawning reliability and performance, larval sensitivity and cannibalism.

Despite the success of other cultures sciaenids, less is known about the cultivation requirements and production performance of black jewfish, with few successful examples reported. Currently research and some production is occurring in China (Chen et al., 2011, Lin, 2004, Shi et al., 2004; Zhang et al., 2006) and Vietnam (Van Thuong et al., 2024). Existing studies have focused on broodstock management, induced spawning and larval rearing techniques. In the NT, the Darwin Aquaculture Centre (DAC) has begun to address concerns regarding the declining wild stocks. Cultivating black jewfish for stock enhancement was commenced in 2018, with the first successful captive spawning taking place in 2020. This demonstrated the feasibility of hatchery production using established intensive culture methods at the DAC. Hatchery protocols were built upon existing hatchery manuals for barramundi *Lates calcarifer*, a tropical finfish species cultured at the DAC (Schipp et al., 2007) and mulloway *Argyrosomus japonicus*, a temperate sciaenid with well-established hatchery production methods (Fielder and Heasman 2011). Research at the DAC has since expanded to address questions regarding the commercial potential of black jewfish aquaculture for both flesh and swim bladder markets. This work has been undertaken within a partnership between the Northern Territory Government (NTG), the Cooperative Research Centre for Northern Australia (CRCNA) 2023-2026, and local aquaculture industry partners. Throughout the three-year project, the DAC has successfully undertaken ten small-scale production runs and eight experimental trials on larvae and juveniles, producing approximately 120,000 black jewfish fingerlings.

While significant progress has been made towards reliable black jewfish aquaculture, several biological and technical constraints continue to limit production. The first significant constraint is the inconsistent reproductive performance of broodstock, with spawning induction and broodstock husbandry methods still being refined. The second major challenge occurs during the late larval rearing and early juvenile phases, when cannibalism can cause severe tail deformities and mortality. This manual consolidates current

knowledge and operational procedures developed through black jewfish aquaculture research at the DAC to support consistent hatchery production and future industry development.

1.4. Purpose of this Manual

This manual describes the current hatchery production protocols developed and refined at the DAC for broodstock management, induced spawning, larval rearing and juvenile production of black jewfish. It provides an operational document for hatchery staff and is a record of technical knowledge gained through successive production and larval and juvenile experiments over the past six years, including research currently in the early stages of scientific publication.

The procedures outlined here represent current best practice and are intended to support operational consistency as well as to facilitate further refinement of described protocols. A summary table of current best practice black jewfish culture parameters and a larval rearing standard operating procedures schedule is also included in Appendices A and B.

2. Seawater Supply

Seawater for the DAC is pumped from Darwin Harbour by two stainless steel, submersible pumps. The water passes through a primary bank of 12 high volume, deep-bed sand filters which effectively remove 98% of particles greater than 10 µm (this is the centre's primary filtered seawater). This seawater is stored until needed in a 30 000 L header tank from where it can undergo secondary filtration removing particles over 5 µm through a bank of five, low volume, deep-bed activated filter media glass filters into a second header tank (this is classified at the DAC as ultra filtered seawater). Filtered seawater is used in broodstock and nursery systems, and ultra filtered seawater is used to supply the larval rearing and live feed areas of the hatchery. Salinity of the incoming water can range from 24 ppt in the wet season (December to March) to 33 ppt in the dry season.

2.1. Broodstock Holding Systems

Filtered seawater is supplied to partial recirculating aquaculture systems for black jewfish broodstock which reuses 80% or more of the system water (Figure 1). These systems are designed to maximise water quality while minimising water consumption. Recirculating water exiting the tank is pumped through a sand filter for the removal of suspended solids before entering a protein skimmer, which removes fine particulates and dissolved organic compounds. The water is then passed through a biological filter where nitrifying bacteria convert toxic ammonia and nitrite into less harmful nitrate, and lastly through a UV sterilisation unit to reduce microbial and pathogen loads before returning to the tank. Filtered seawater is continuously added to the system to replenish volume and optimal water quality. Temperature, salinity, dissolved oxygen and pH are recorded daily and ammonia, nitrite and nitrate are recorded weekly.

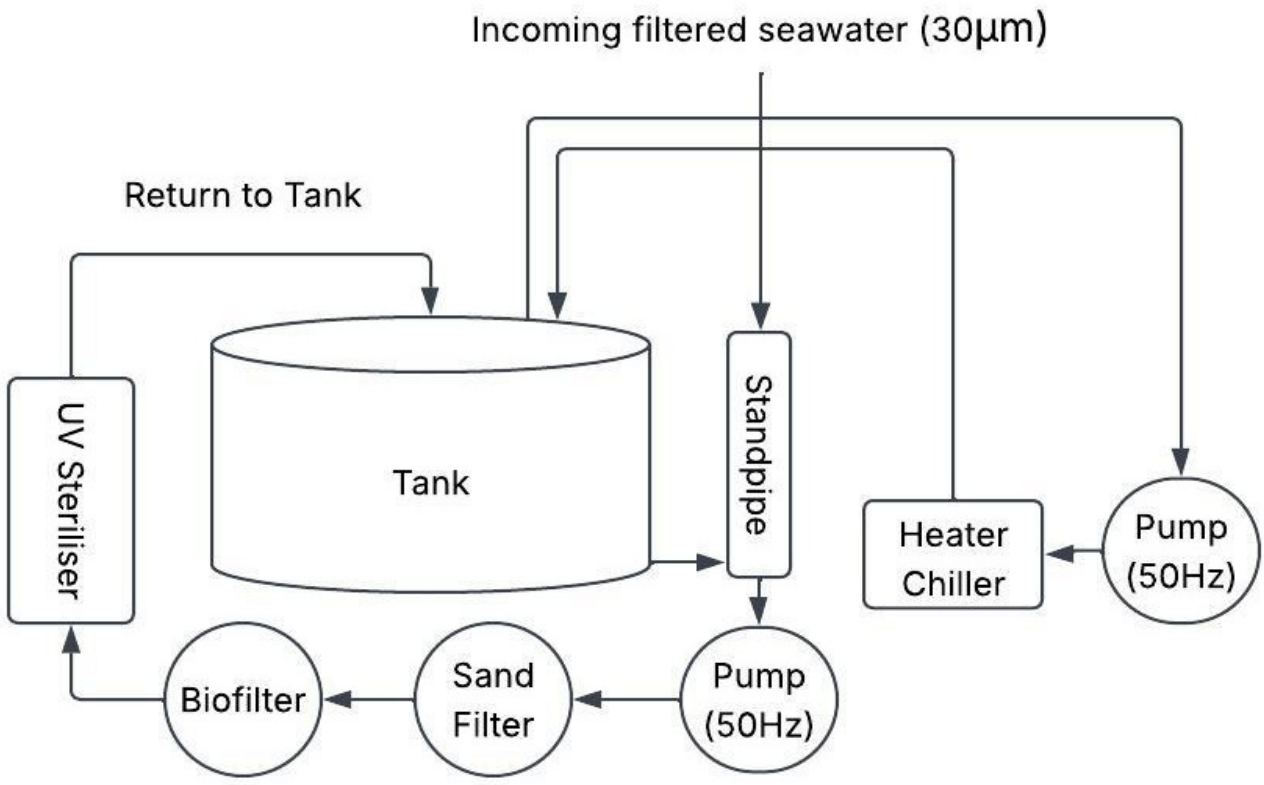


Figure 1. Seawater filtration system for black jewfish *Protonibea diacanthus* broodstock holding recirculating aquaculture systems at the Darwin Aquaculture Centre. Infrastructure and filtration components are labelled, and arrows denote water flow in broodstock holding tanks.

2.2. Hatchery Systems

Ultra-filtered seawater is supplied to larval rearing and live feed systems after undergoing further filtration to prevent water borne pathogens from entering the hatchery. A pathogen of particular concern to early life stages of marine fish larvae at the DAC is nodavirus. Nodavirus is endemic in Darwin marine waters and adult fish may carry the virus without displaying any signs of infection. However, nodavirus is often lethal to larvae and juvenile fish and has caused numerous disease events in barramundi at the DAC before the routine use of UV sterilisation of incoming seawater and biosecure hatchery rooms. Nodavirus is difficult to inactivate, so all hatchery seawater treatment is aimed to sterilise at a level appropriate to prevent nodavirus from entering. Ultra filtered seawater is filtered through 5 micron and then 1 micron filter bags and then passes through a UV steriliser (Pentair E150S-230 (150 W)) (Figure 2). The water flow rates through the UV are kept between 30-50 L/min (373-224 mJ/cm2) in the DAC larval rearing system to control for nodavirus.

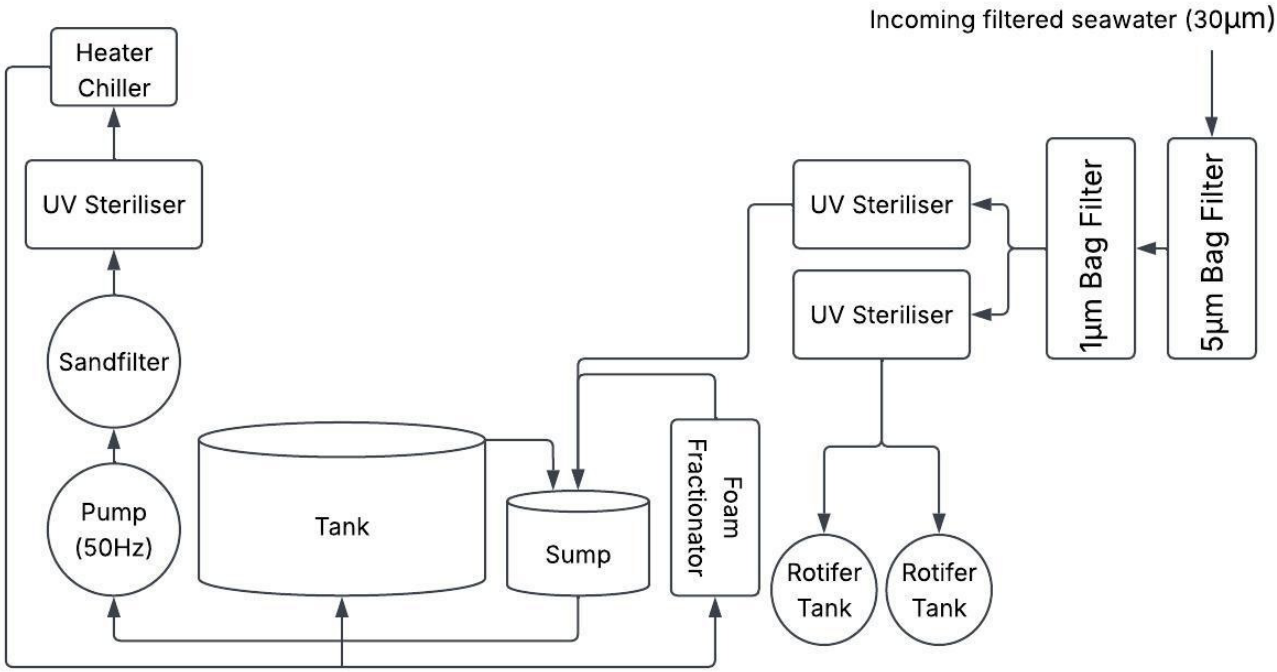


Figure 2. Seawater filtration and sterilisation system for black jewfish *Protonibea diacanthus* larval and live feeds hatchery systems at the Darwin Aquaculture Centre. Infrastructure and filtration components are labelled and arrows denote water flow.

3. Broodstock

The following protocols reflect current practices developed and used at the DAC. Facilities adopting these protocols may adapt them to suit site-specific infrastructure and operational requirements.

3.1. Capture and Transport

Successful broodstock collection begins with careful planning of activities to minimise stress, injury and post-capture mortality. An important consideration when catching black jewfish is their vulnerability to barotrauma and capture stress. As fish size and the capture depth increase, the incidence of barotrauma also increases, and the impacts become more severe. Larger black jewfish are much more susceptible to capture mortality, and early attempts to capture large, sexually mature fish (approximately 1m length) in Northern Territory waters resulted in very low post capture survival. To mitigate this problem, broodstock are now collected from shallow coastal areas, where there is confirmed presence of small (<50cm) individuals. Populations of smaller fish at depths between 2-7m are ideal for broodstock collection. Liaising with local fishers and fishing tourism operators can be a useful way to identify such locations.

Wild black jewfish individuals are caught via hook-and-line from a boat. The collection boat is fitted with a plastic transport tub (~500L) to efficiently capture and transport fish back to shore and filled with seawater collected at the fishing location (Figure 3A). When caught, fish are immediately placed in the tub and monitored for signs of barotrauma. After the desired number of individuals have been captured, the transport tub is secured with a net or lid and water quality is monitored for transport back to shore. Up to 15x 50cm fish can be held in a transport tub of this size for travel distances of less than 2 h. An oxygen source and a diffuser is always available and is used if dissolved oxygen levels drop.



Figure 3. Black jewfish *Protonibea diacanthus* wild broodstock collection equipment used by the Darwin Aquaculture Centre. Image A shows fishing boat with transport container and fitted lid (mango bin, 500L) with small pump and hose inside used to fill with ambient seawater at collection location. Image B shows transport trailer fitted with custom built tank and oxygen for movement of live wild caught fish to the centre.

Once on shore, fish are moved from the boat with slings or nets into a dedicated fish transport tank (Figure 3B). The transport tank is filled with seawater matched as closely as possible to the source location and kept under 31 °C if possible. The transport tank is fitted with an oxygen bottle and diffuser to ensure dissolved oxygen can be maintained close to 100% saturation for the duration of the journey. Upon arrival at the hatchery, fish are transferred to quarantine holding tanks.

Quarantine remains the most important disease prevention measure and serves as a facility's first line of defence against the introduction of infectious disease and/or their spread. At DAC new broodstock are kept in quarantine tanks (generally 10 000 L volume) for a minimum of two weeks. These tanks are physically isolated from resident fish populations and can be monitored closely for any signs of disease. Quarantine tanks are clearly signed and have dedicated foot baths and hand-sanitiser stations. Daily operations are adjusted to ensure that staff attending quarantined fish do not spread potential pathogens throughout facility. For example, a dedicated quarantine staff member will shower and change after completing quarantined fish husbandry before returning to tasks across the facility. All equipment and feed required for husbandry are also kept isolated. These steps are necessary to minimise the risk of potential pathogen spread to other parts of the facility. At the DAC, targeted and prophylactic chemical treatments, as described in the following sections, have been used during quarantine in consultation with an aquatic veterinarian. Where necessary, two quarantine tanks have been used to facilitate tank changes to maximize treatment success for certain pathogens. Quarantine is only concluded once fish are feeding normally, free from signs of disease and have completed any required treatment protocols, with a minimum of two weeks. Records of quarantine and treatments for each batch of fish are kept for future reference.

Following successful quarantine, all broodstock are individually identified by insertion of passive integrated transponder (PIT) tags. Tagging enables accurate record keeping for age, growth, sex determination, spawning history and genetic management. PIT tag implantation is conducted under heavy sedation (Appendix E), with tags inserted into the dorsal muscle using a sterile needle (Figure 4). Following insertion, tag identity is scanned, verified and entered into a broodstock database.



Figure 4. Heavily sedated, sub-adult black jewfish *Protonibea diacanthus* being injected with passive integrated transponder tag at the Darwin Aquaculture Centre. The tag is inserted in the dorsal musculature approximately three scales below the dorsal fin and in line with the pectoral fin.

3.2. Housing and Diet

Broodstock at the DAC are maintained in partial recirculating seawater systems ranging from 15 000 to 45 000 L in volume, as described in section 2.1. Temperature and salinity are generally maintained at ambient seasonal levels, although temperature manipulation using heat-chill systems may be employed when out-of-season spawning is required. Salinity can range from 24 ppt in the wet season (December to March) to 33 ppt in the dry season, with ambient temperatures between 24-33 °C. Aeration is provided to maintain dissolved oxygen near saturation while ensuring gentle water movement throughout the tank. Water quality parameters are monitored and maintained within ranges suitable for black jewfish broodstock (Appendix A, Table 1, and Appendix C).

Stocking density is kept below 10 kg/1000 L to minimise stress and maintain water quality. At the DAC, broodstock are typically held at densities between 1–7 kg/1000 L depending on tank and fish cohort sizes. At higher densities, dissolved oxygen can decrease significantly in warmer months, particularly when intraspecies aggression occurs.

Wild-caught broodstock require a nutritionally complete and varied diet to support gonadal development and reproductive conditioning. At the DAC, fish are fed a mixed diet designed to replicate natural nutritional diversity while ensuring adequate lipid and protein intake for gamete production. Defrosted, locally sourced squid, mullet and prawns are fed alongside INVE Aquaculture Breed-M pellets, a commercial broodstock conditioning feed, to improve spawning performance. Breed-M is fed at 20% of total feed in the 3 months leading up to a spawn induction. Broodstock are generally fed 3 times per week to satiety, adjusted according to feeding response, approximately 3-5% body weight. Feeding behaviour is monitored closely, as reduced appetite is often the earliest indication of stress or disease.

3.3. Disease Management

Routine monitoring of broodstock health is essential. Behavioural indicators requiring immediate investigation include reduced appetite, abnormal swimming behaviour, flashing (swimming sideways or rubbing themselves on the tank floor), prolonged surface swimming, visible lesions, scale loss, eye damage, fin erosion, and changes in skin colouration. Daily observations are recorded systematically and retained for veterinary review where diagnosis or intervention is required. A daily fish observation checklist is used to ensure optimal broodstock health and surveillance, mitigating gaps in fish observations during times of staff turnover and busy periods (Appendix C).

Effective disease prevention is essential for maintaining broodstock health and ensuring consistent reproductive performance. Biosecurity and treatment protocols are developed and implemented in consultation with an aquatic veterinarian and must include appropriate staff training. Wild broodstock and infected/diseased fish are always isolated from established fish cohorts. Biosecurity plans clearly define staff responsibilities, disinfection protocols, movement restrictions and equipment requirements necessary to achieve the desired outcomes.

3.3.1. Common Diseases and Parasites

Common health challenges encountered in black jewfish broodstock in our region over the past 3 years are ectoparasitic infestations including leeches (*Zeylanicobdella sp.*), gill flukes (*Diplectanum sp.*) and marine velvet disease (*Amyloodinium sp.*). These parasites reduce feeding, inhibit respiration and cause mortality if left untreated. Refer to section 3.3.2 for gill clip diagnostic protocol and section 3.3.3 for treatment protocols at the DAC.

3.3.1.1. Marine leeches

Marine leeches were first detected during broodstock collections in 2023, where significant loads of marine leeches were noted on the operculum and mouths of collected fish after capture, leading to mortality of several fish. Checking for the presence of leeches in new broodstock is an important step as they require a targeted treatment regime. Marine leeches are visible to the naked eye (Figure 5) and easily identifiable in monitored quarantine tanks. The marine leeches observed were morphologically consistent with *Zeylanicobdella sp*. (personal communication with marine parasitologist, Dr Di Barton), although this identification has not been genetically confirmed.

Leeches threaten fish health through damage at attachment sites from secondary infections and inflammation, blood loss from consumption and anticoagulant secretion by the leeches, and potentially as a vector for other pathogens. Additionally high leech loads may have other health effects on fish through their adverse impacts to gaseous exchange, nitrogenous waste excretion, and ion and acid-base regulation from structural gill damages and inflammatory responses, if gills are their attachment sites, and manifestations of abnormal behaviours such as increased flashing and reduced feeding.

Several treatment types were administered initially (freshwater and hydrogen peroxide), supported by literature on leech infestation treatment using freshwater (Chu et al., 2019; Kua et al., 2010). However, they were not effective at killing or removing the leeches, considering black jewfish are not a euryhaline fish species capable of surviving salinities low enough to permanently remove leech infestations. Formalin treatments (Lacierda, 2000), as described below, were successful in eradicating leeches when used one week apart in addition to tank changes immediately after each treatment. Noting that formalin treatment does not kill the leeches, but it makes them drop off the fish and to the tank floor. For this reason, it is essential to move fish out of the tank before leeches have time to recover and reattach.

Multiple treatments are used to ensure that all adult and any newly hatched juvenile leeches, from the chemical resistant egg cocoons in the environment, were cleared from the system before fish are introduced into broodstock populations at DAC. Leeches can be confirmed as removed through visual inspection of the fish epidermis.

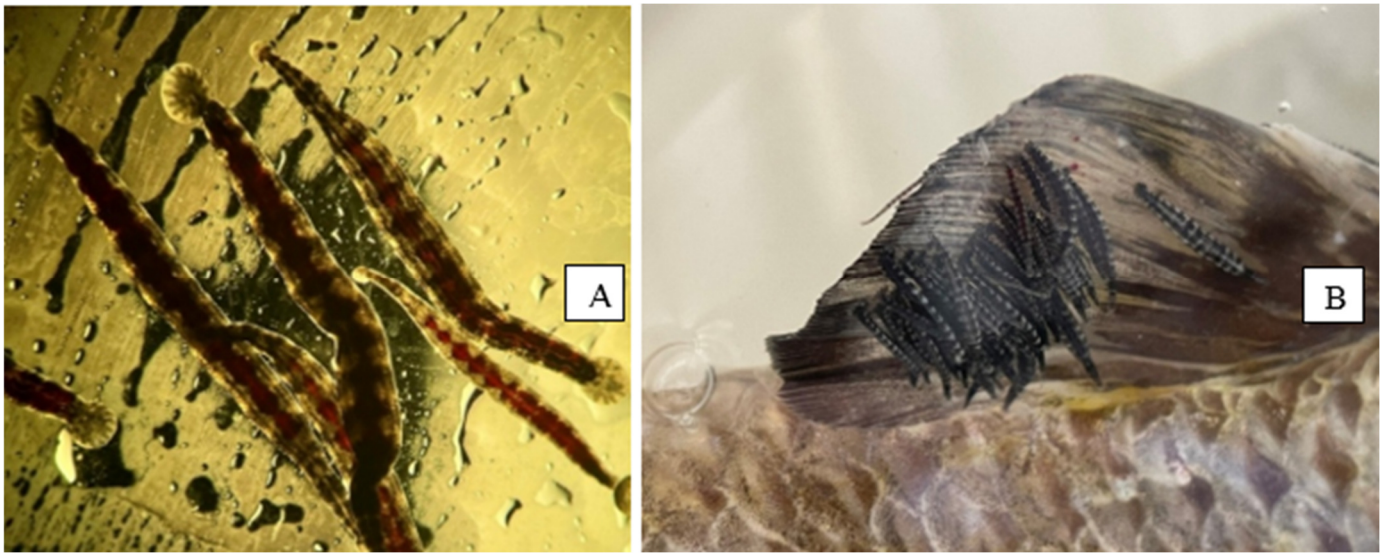


Figure 5. Marine leeches *Zeylanicobdella sp*. infestation on wild caught black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre. Leeches are shown A.) microscopically, and B.) on fins.

3.3.1.2. Amyloodiniosis

Amyloodiniosis caused by the parasitic dinoflagellate *Amyloodinium ocellatum*, has been a recurring problem in broodstock black jewfish at the DAC. Interestingly, other finfish species on site have not been affected by this endemic parasite to the same extent. This parasite is common in tropical marine environments worldwide, including in the waters of the NT. The parasite infects the gills, fins and skin of marine fish, and black jewfish housed at the DAC have experienced multiple outbreaks, sometimes resulting in substantial mortalities. The first signs of infection in broodstock are reduced feeding, and changes in skin mucus and swimming behaviour. As the parasite load increases over time and the disease progresses the fish gills can become overwhelmed with parasites. This can be seen as gasping or surface swimming behaviours. Confirmation of infection is via wet-mount microscopic inspection of gill clips, as described in section 3.3.2, or skin scrape smears from behind the pectoral fins. *Amyloodinium trophonts* can typically be identified microscopically as dark, sessile, spherical structures ranging from 15–40 µm in diameter (Figure 6).

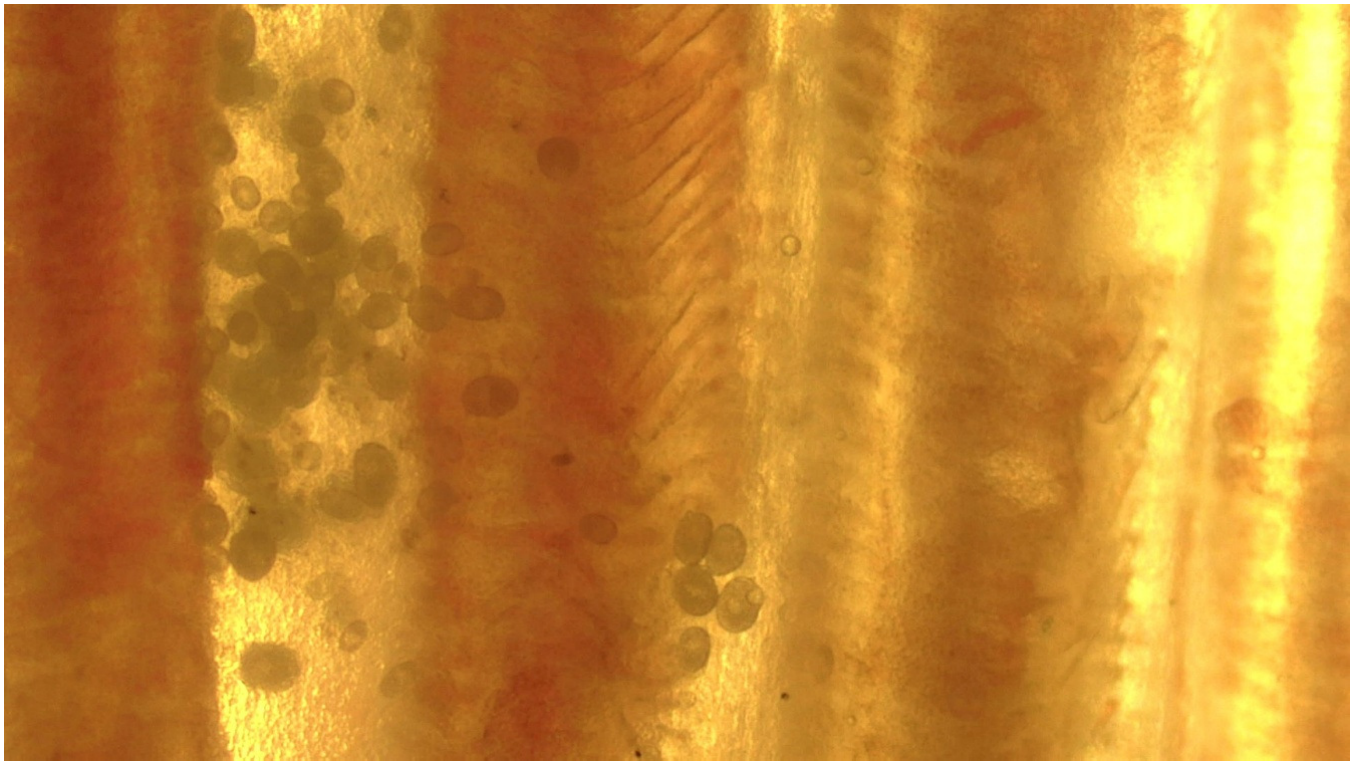


Figure 6. Microscopic image of Amyloodinium infestation on black jewfish *Protonibea diacanthus* gills at the Darwin Aquaculture Centre (40x mag Leica compound microscope)

The distinct life stages of *Amyloodinium* adds an additional layer of complication to management of the disease (Moreira et al., 2022). The dinospore stage (the free-swimming infective stage) and trophont stage (the sessile feeding stage) of *Amyloodinium* are susceptible to chemical treatments. However, as they grow and detach from the fish to turn into tomonts (the reproductive cyst stage) in the environment, they are resistant to most chemical treatments. The tomonts will undergo internal cell division exponentially within the cyst. After the cyst matures and ruptures, the infective diospores are released to swim through the water column and seek new susceptible hosts or reinfect the fish to begin another life cycle. The parasite reproduces every 3-4 days at warm water temperature (around 30 °C). To break its life cycle, treatment at

the DAC involves two treatments of hydrogen peroxide spaced 6 days apart. The hydrogen peroxide is administered at a dosage between 75-150ppm for 1 hour (depending on water temperature, the higher the temperature the lower the dose rate) in consultation with an aquatic veterinarian. Infected tanks are vacuumed daily in between both treatments to remove any developing and freshly dropped tomonts, or fish are relocated to a clean tank after each treatment. In addition to chemical treatment, strict biosecurity measures, equipment disinfection and routine health monitoring are essential for minimising the risk of recurring outbreaks.

3.3.1.3. Gill flukes (Monogenean infestations)

Monogenean parasites are often recorded in gill clips of black jewfish during routine health monitoring. Monogenean parasites are endemic in the NT waters and often persist at low levels in various species of finfish broodstock populations at the DAC, and at times cause significant health impacts, particularly in black jewfish. *Diplectanum sp*. is most commonly encountered in black jewfish at DAC. While low levels of these parasites do not interrupt fish function and behaviour, stressed or weak fish are susceptible to increased parasite loads which can have significant health impacts. Stress and an increased parasite load can cause significant gill damage to fish and make fish more prone to secondary bacterial infections. Signs that fish are affected by a monogenean infection include excess mucus, feeding reduction, flashing and changes in swimming behaviour. As parasites overload the gills, the fish will eventually be unable to perform gaseous exchange, nitrogenous waste excretion, and ion and acid-base regulation, resulting in mortality. Confirmation of infection is performed through immediate examination of a wet-mount preparation of gill clips, as described in section 3.3.2. In a fresh preparation, this parasite is often pivoting vigorously side by side at its attachment site; and the parasites is characterised by elongated shaded/dark shape with 4 eye spots anteriorly and distinct hooks and squamodisc structures posteriorly that allow them to attach to the gill filaments (Figure 7). Routine gill health screening should form part of broodstock health monitoring, particularly prior to spawning inductions, transport or major handling procedures.

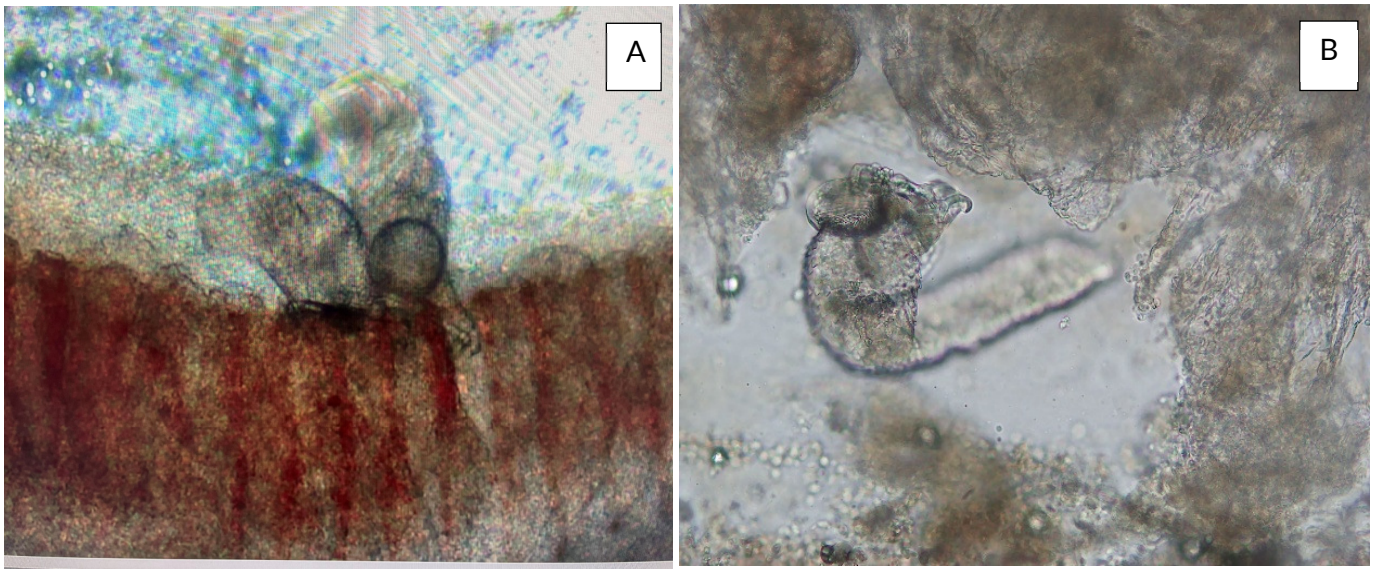


Figure 7. Gill flukes (*Diplectanum sp*) infestation on farmed black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre. Flukes are shown microscopically at 100 x magnification A.) with squamodisc and hooks for attachment to gill filaments and B.) fluke detached from the disintegrating gill filament in an older wet-mount preparation that had been left on the bench for more than 30 minutes.

At the DAC, treatment of gill fluke infestations is typically achieved using hydrogen peroxide or formalin. Following treatment, fish are monitored closely for improvements in feeding behaviour, respiratory rate and general condition. Follow-up gill biopsies are done where practical to determine whether additional treatment is required. Maintaining optimal water quality, minimising handling stress, implementing strict quarantine procedures for new broodstock, and regular monitoring coupled with early treatment remain the most effective strategies for reducing the incidence and severity of gill fluke infestations within the broodstock populations.

3.3.2. Parasite Diagnostic Procedures

Parasites are diagnosed at the DAC though examination of gill clips under a microscope. Gill clips are obtained during routine health monitoring and disease management, or opportunistically during tank changes and pre-spawning procedures, such as gonad cannulation to assess sexual maturity, when fish are already under sedation. This procedure is performed by two trained staff members on fish under heavy sedation to minimise injury and stress to fish (Appendix E). Prior to sampling, all staff members disinfect hands and equipment with 70% isopropyl alcohol. Once fish is heavily sedated the operculum is held open by one staff member and the other uses sharpened scissors to remove approximately 2 mm x 2 mm of gill filaments from the tips (Figure 8A). Once removed from the fish, the gill clips are placed gently on a clean microscope slide by tweezers and a drop of tank water is added before a cover slip is placed over to secure the gill clips for wet mount microscopic examination. Immediate examination of the gill clip is performed under a compound microscope for accurate identification of pathogen and load while the parasites are still moving (Figure 8B). If the gill clip sample is too thick, light penetration through the sample may not be adequate for gill fluke detection and identification, and in this case a scalpel can be used to slice through the sample and create a thinner preparation. A microscope with camera attached is used to allow images to be taken for record keeping and subsequent identification by other aquatic health professionals as necessary.

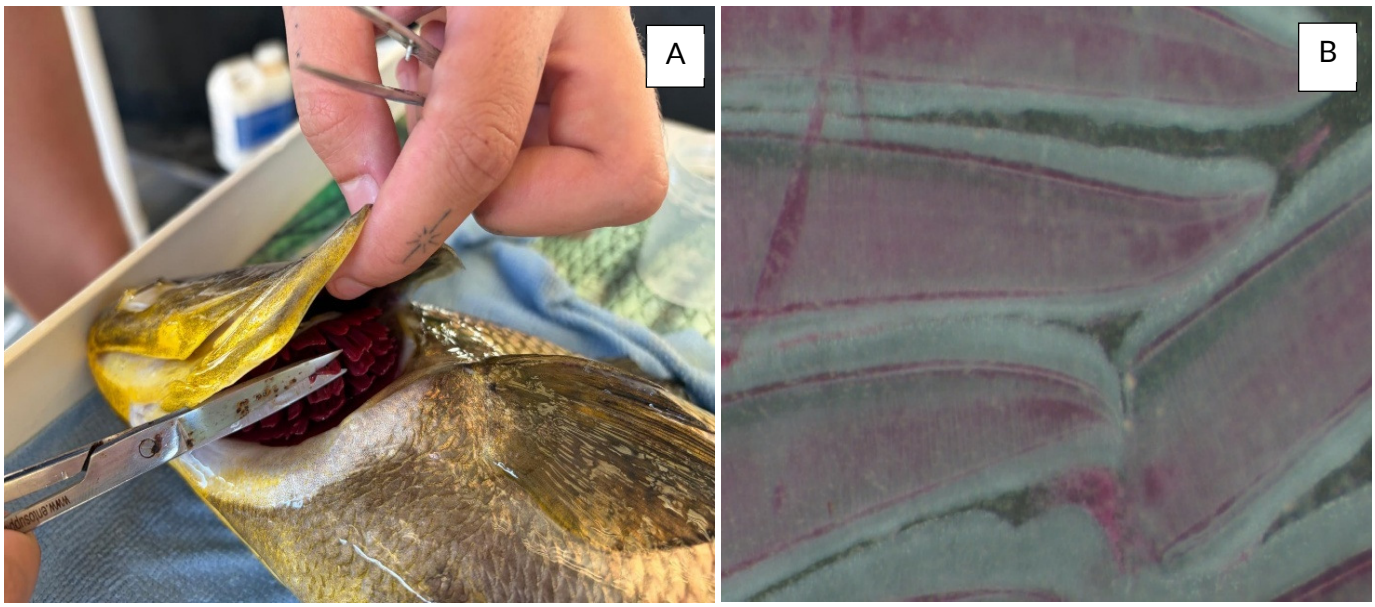


Figure 8. Image showing gill clip sampling of a sub-adult black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre. Image A shows sampling of a healthy black jewfish gills and B shows a healthy gill filament microscopically.

3.3.3. Parasite Treatment Protocols

Ectoparasitic treatments used at the DAC are varied depending on infestation levels but generally rely on off-label usage of formalin or hydrogen peroxide to detach or destroy the ectoparasites. Off-label use of these chemicals is covered by valid minor use permits from APVMA (Australian Pesticides and Veterinary Medicines Authority) and in consultation with an aquatic veterinarian. Prophylactic usage of these chemicals in low therapeutic doses had been applied during quarantine and immediately prior to spawning conditioning based on gill biopsy findings. While prolonged freshwater immersions are commonly used as a non chemical-based treatment in barramundi broodstock, this method has proved to be highly stressful for black jewfish. However, reducing salinity gradually over days and weeks to a minimum of 8 ppt can be an effective way to provide osmoregulatory support to reduce stress caused by non-emergency events, such as post handling recovery. Treatment records are kept for review and future reference.

3.3.3.1. Hydrogen peroxide treatment

The optimal dose and the required volume of hydrogen peroxide is dependent on the water temperature in the treatment tanks and the specific product used, as per APVMA minor use permit PER88576. Typical treatments at the DAC are administered at 75–150 ppm for one hour. Broodstock fish are not moved prior to treatment and water level in housing tanks is not altered. Incoming water is turned off prior to treatment and light aeration is maintained. Pre-diluted H_2O_2 is introduced into the tank slowly and at different locations (~500ml mixed with ambient tank water in 20L bucket) to prevent the occurrence of chemical “hot spots” in the water column. After ten minutes all recirculating pumps are turned off to facilitate bathing of fish. Strict record keeping is performed during treatments, where water quality and fish behaviour is monitored closely over the hour (Appendix D). Typically, the dissolved oxygen levels in the tank will increase slightly during the treatment when the hydrogen peroxide is degrading into oxygen and water. After the treatment period, incoming water can be turned back on and there is no need to flush the chemical out of the tank. Fish generally tolerate hydrogen peroxide well at DAC and they can be moved into clean tanks after the treatment as necessary. Thorough vacuuming of the tank post treatment is essential to remove detached parasites or cystic stage of the parasites that are resistant to chemical treatment to prevent reinfection, if fish are not immediately moved to a clean tank. Hydrogen peroxide should be handled using appropriate personal protective equipment (PPE), including gloves and eye protection.

3.3.3.2. Formalin treatment

As per the APVMA permit’s conditions of use, PER94717, the dosage and method of application of formalin necessary to control external parasites depends on the species being treated and a number of other factors (e.g. water quality, stocking density, water temperature, level of infestation and parasite species being treated). Immersion formalin bath dosage can be up to 200 ppm and the fish are treated for one hour. When treating with formalin, incoming water to treatment tanks is turned off and the water level is reduced to approximately 25% of the holding capacity to reduce the amount of formalin product required. Aeration must be maintained throughout the treatment period. Additionally, if multiple tanks are available, then fish can be treated in one tank prior to being moved into the clean tank. Formalin is introduced slowly to the tank (~200-500ml mixed in a 20L bucket) and distributed at different locations to prevent chemical “hot spots”. Recirculating pumps should be turned off to facilitate bathing of fish. Fish

should be monitored closely over the treatment period, with water quality, particularly dissolved oxygen, and fish behaviour recorded throughout treatment. Close attention should be paid to dissolved oxygen levels, and it is likely that compressed oxygen will need to be introduced to the tank as formalin and the increased respiration of stressed fish will reduce available levels. Prior to treatment a dedicated oxygen bottle with working oxygen diffuser should be set up at the treatment tank for emergency application. After the treatment, if fish are remaining in the treatment tank, the incoming water should be introduced at a high exchange rate to ensure that remaining formalin is further diluted out and removed as quickly as possible. Formalin is a hazardous chemical and must be handled using appropriate PPE, including gloves, eye protection and respiratory protection where required under workplace safety procedures.

3.4. Spawning

Black jewfish are induced to spawn at the DAC after satisfactory gonad biopsy assessment via cannulation to assess sexual maturation microscopically. Sexually mature fish are induced to spawn by intramuscular injection with luteinising hormone-releasing hormone analogue (LHRHa) (Syndel Laboratories, 5mg spawning peptide powder, Canada) reconstituted in saline, using methods described in Schipp et al. (2007) and Fielder and Heasman (2011). Success in inducing high-quality spawns of black jewfish at the DAC has been variable. Further work is needed to understand gamete conditioning, particularly male fish, the ideal spawn induction product and administration method, and synchronicity of gamete release between sexes.

Cannulation is performed under heavy sedation using eugenol-based anaesthetic products, such as SED8 and AQUI-S. These have proven effective for sedation and handling of black jewfish broodstock for the purpose of cannulation and spawn induction. Anaesthetic dose depends on procedure, with light sedation used for handling and heavy sedation used for cannulation. All sedation dosages are carefully monitored (Appendix E). All chemical storage and usage records are maintained in accordance with facility and regulatory requirements.

Prior to handling, broodstock holding tanks are partially drained to knee depth to facilitate capture. Figure 9A shows a typical broodstock anaesthesia and cannulation set up. Light sedation can be applied to the holding tank to reduce handling stress during capture. Fish are gently caught in a sling and transferred to a dedicated anaesthetic tank one at a time with the anaesthetic bath maintained at a dosage sufficient to induce heavy sedation. The sedation tank is aerated and dissolved oxygen is monitored closely throughout the process. Once a fish loses its balance and is upside down with much reduced body movement and steady gill movement, cannulation can proceed. Inserting the cannula before a fish is heavily sedated can damage the delicate genital opening of the fish. Females have three openings and males have two, and they do not change sex through their life. Sperm is cannulated through the opening closest to the tail of male fish and oocytes are cannulated from females through a middle opening that does not exist in males. Figure 9B shows positioning of the cannula in female black jewfish to extract oocyte samples. A microscope is set up next to the tank to make quick assessments on gonad maturity. Females are considered reproductively ready when oocytes measure approximately 400–500 µm and are uniform in size, have a spherical shape and good separation (Figure 10). Males are selected based on the volume and activity of sperm.

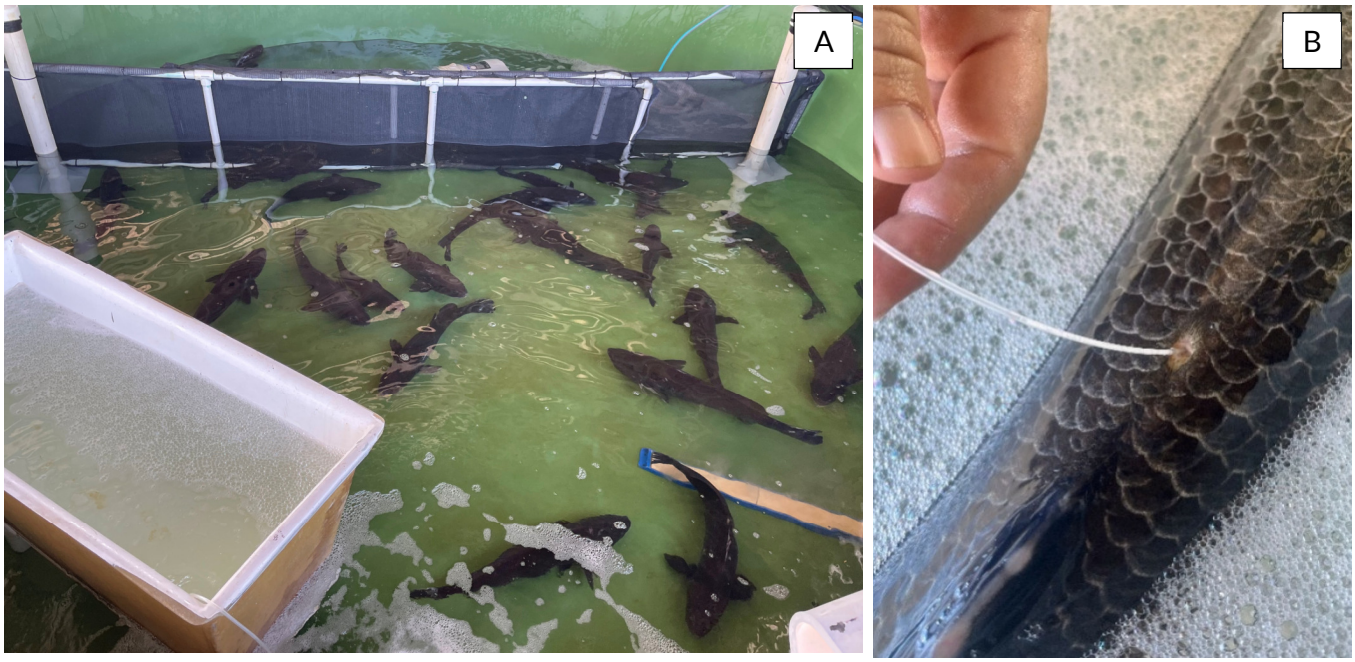


Figure 9. Cannulation of black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre to assess sexual maturity. Image shows A.) tank set up with tub for administering anaesthetic and undergoing cannulation, and divider for separating cannulated fish and B.) placement of cannula in female black jewfish genital opening with oocyte retrieval.

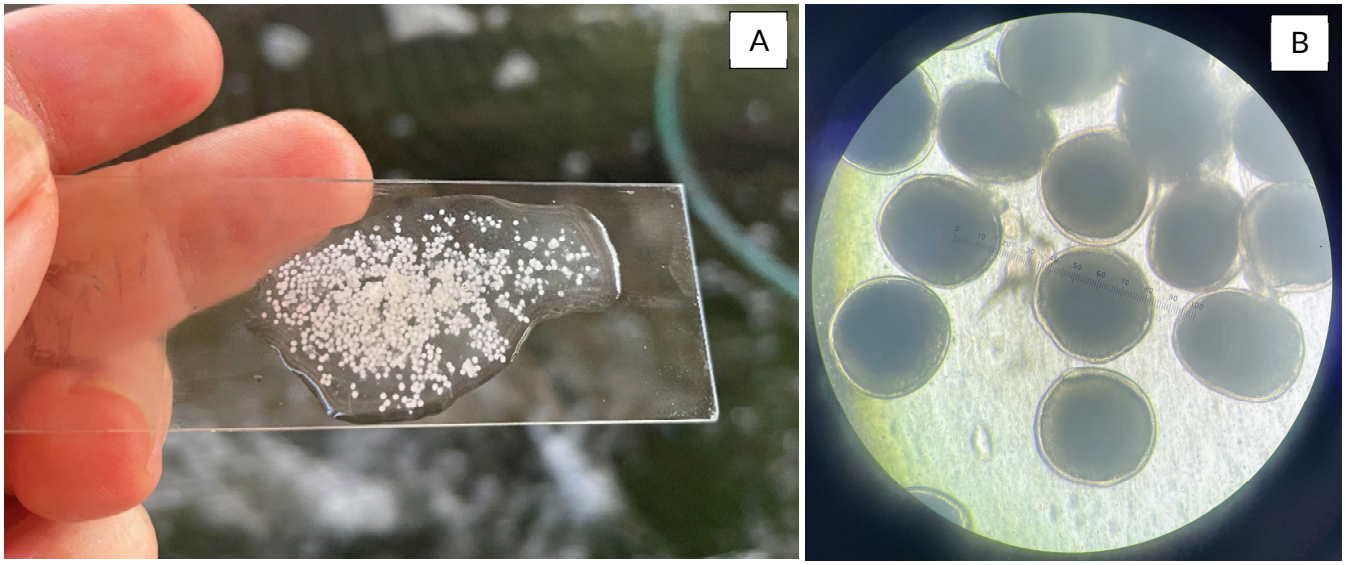


Figure 10. Oocytes obtained through cannulation from black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre on A.) slide and B.) under microscope, measuring 450-500 µm diameter.

After cannulation, the length and weight of the fish is measured in a sling and then the fish is placed into the recovery area. Fish are held upright in clean seawater with water flowing via submersible pump into the mouth to ventilate the gills until they are revived enough to swim away. Fish are monitored closely during anaesthetic recovery and recovery procedures are recommenced if fish turn upside down again. All details are recorded against each fish's ID in a computer database, see Appendix F for an example of data collection.

Typical spawning groups consist of one female paired with two to four males. At the DAC, females generally enter reproductive condition more consistently than males. Farmed females at the DAC have returned high quality oocytes at cannulation, but farmed males of the same cohort have not returned sperm samples to date. Black jewfish have been primarily induced to spawn in large broodstock holding tanks rather than in the smaller 5000 L spawning tanks used for barramundi at the DAC.

All selected broodstock are weighed to determine the precise amount of spawning peptide to be administered. Spawn induction is achieved using LHRHa administered at 50 $\mu g/kg^{-1}$. The lyophilised spawning peptide product is reconstituted with a sterile saline solution at 1 mg/ml^{-1}. Fish are either injected under heavy sedation immediately post cannulation, or after recovery (Figure 11A). Handling stress can be reduced by gentle capture of the fish in a sling under light sedation. Fish remain submerged in the sling, with their eyes covered with a wet soft cloth to keep them calm and prevent injury to the eyes. Spawning peptide is injected intramuscularly at a site approximately three scales below the dorsal fin in line with the pectoral fin.

Black jewfish are broadcast spawners and viable (fertilised) eggs will float to the surface of the tank shortly after release, usually between 24-30 hours post spawning peptide injection. Fish will often make loud croaking, or drumming sounds during the lead up to and during spawning events. Egg collectors are installed on outflows of the spawning tank following spawning peptide administration (Fig 11B). Although spawning most commonly occurs at dusk on the day following induction, collectors can capture any earlier spawning activity. Collectors consist of 250 µm mesh nets positioned at tank outflow to capture floating eggs as they are flushed out of the tank. Recirculation pumps are disabled to prevent egg damage and entrapment in the tank's filters, while incoming new water flow rates can be increased to encourage egg movement into collectors. Collected fertilised eggs are disinfected prior to transfer to larval hatching systems to minimise the risk of endemic pathogen transfer, particularly nodavirus. The disinfection method adopted at the DAC is ozonation as described by Schipp et al. (2007).



Figure 11. Spawn induction of black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre. Image shows A.) injection of 50µg/kg LHRHa into dorsal musculature of heavily sedated fish and B.) egg collector fitted to overflow of tank to collect buoyant eggs.

4. Larvae

4.1. Egg Stocking and Development

Spawned eggs are disinfected in ozonated water prior to entering the hatchery. A contact time (CT) score of 0.7-0.9 is considered acceptable for disinfecting eggs and inactivating nodavirus (Schipp et al., 2007, Ballagh et al., 2011). After ozonation, eggs are washed in filtered seawater and stocked into a 1000 L aerated hatching tank filled with flow through filtered seawater at 4 L min^{-1} up to a density of up to 3 eggs mL^{-1}. After hatching, small surface skimmers are added to the hatch tank to remove oil and eggs shells and other debris which collects on the floor of the tank are carefully siphoned out.

Key developmental stages of black jewfish eggs are summarised in Figure 12 and described in detail by Taylor et al. (2024). Newly released hydrated eggs typically measure 0.88 mm in diameter with an oil globule 0.24 mm in diameter. Hatching commences at 12 hours post fertilisation (hpf) and is complete within 30 minutes.

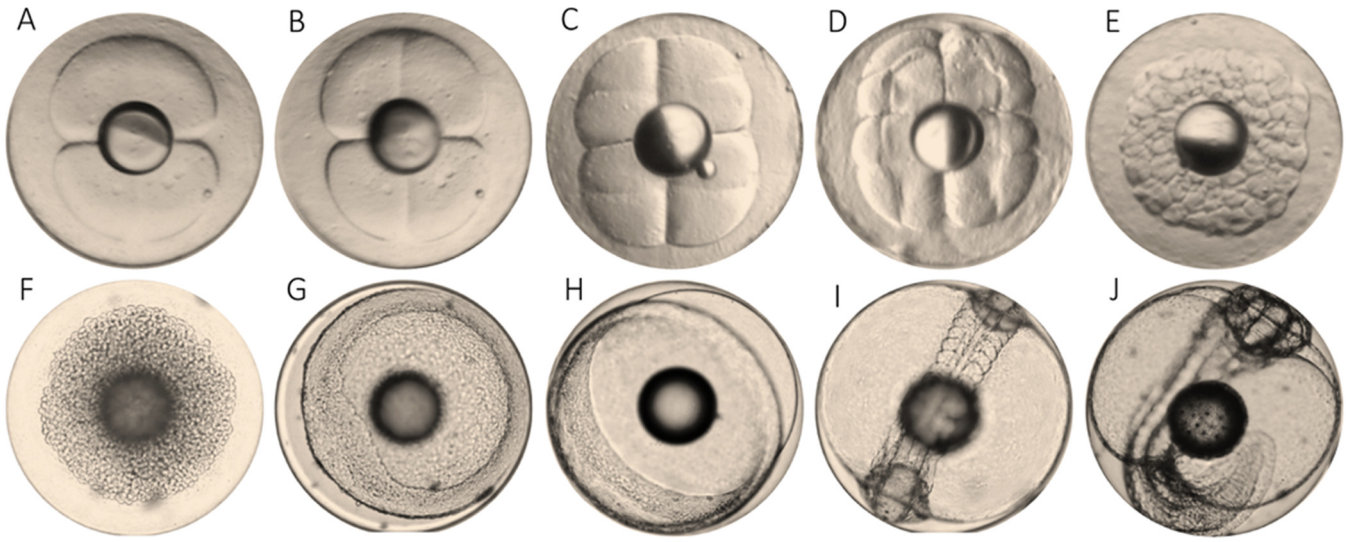


Figure 12. Embryonic development of *Protonibea diacanthus* eggs spawned in captivity at the Darwin Aquaculture Centre at 35 ppt salinity and 30 °C water temperature. (A) 2-cell stage 30 minutes post fertilisation (mpf); (B) 4-cell stage 45 mpf; (C) 8-cell stage 1 h post fertilisation (hpf); (D) 16-cell stage 1.5 hpf; (E) 128-cell stage 1.75 hpf; (F) 512-cell stage 2 hpf; (G) shield 5 hpf; (H) blastoderm extension 6 hpf; (I) neurula stage 8 hpf; (J) embryonic stage 10 hpf. (Taylor et.al 2024)

4.2. Larvae Stocking and Development

Black jewfish larvae are stocked into larval rearing systems approximately 24 hours after hatching. At this stage the larvae are robust enough to withstand gentle handling and movement between tanks but are not so developed that they react significantly to external stimuli, reducing the stress incurred through capture and movement. The hatch tank water chemistry must, as closely as possible, match that of the larval rearing tank to reduce the impact of movement shock to the larvae. It is important to stock larvae into growing systems before their mouths open so they can have access to food as soon as they are ready to feed. The preferred method for stocking larvae is either gently corralling larvae into a 64 or 100 µm net and transferring condensed larvae with a small container. Alternatively, larvae can be condensed in the hatch tank by dropping the water level and using a basin to transfer larvae into the rearing tank/s. Larvae numbers are estimated using 3 x 3ml pipette samples to count larvae for each basin until desired stocking rate has been achieved. Research into stocking densities showed little difference in survival at 22 days post

hatch (dph) between tanks stocked at 10, 40 and 70 fish per litre (unpublished data). However, black jewfish are slightly smaller at 22 dph when stocked at 70 L^{-1} compared to lower densities. Post-metamorphic cannibalism was lowest when larvae were stocked at 10 L^{-1}. Growing larvae at high densities is a more cost effective and efficient way of producing fingerlings, but at the DAC rearing black jewfish larvae at lower densities has typically produced larger, higher quality fingerlings.

Key developmental stages of black jewfish larvae are summarised in Figure 13 and described in detail by Taylor et al. (2024). Larval mouths open by 33 hours post hatch (hph) and swim bladder inflation commences at 40 hph, typically complete by 3 dph and usually with a 95% inflation rate. Food has been observed in larval stomachs from 57 hph, with all fish feeding by 3 dph. At 10 dph larvae average 4.8 mm standard length (SL) and begin undergoing tail flexion. Larvae typically display full caudal fins by 15 dph along with black skin pigmentation around the gut and gills and an average SL of 5.6 mm. The completion of flexion coincides with the beginning of cannibalistic behaviour at 16 dph, with larger fish observed predating on smaller larvae and biting the posterior end (i.e. tails) of larvae of all sizes. By 20 dph larvae the average 10.2 mm SL and display juvenile body features such as an elongated caudal fin, full fin ray development and more extensive black pigmentation in the skin. At 23 dph average SL of black jewfish is typically 13 mm, and most fish have either completed or almost completed metamorphosis. At this point fish are ready to be graded and transferred into nursery systems. Delaying grading beyond this point can result in severe cannibalism-related mortality. Laboratory batch health check samples are often collected between 20-23 dph.

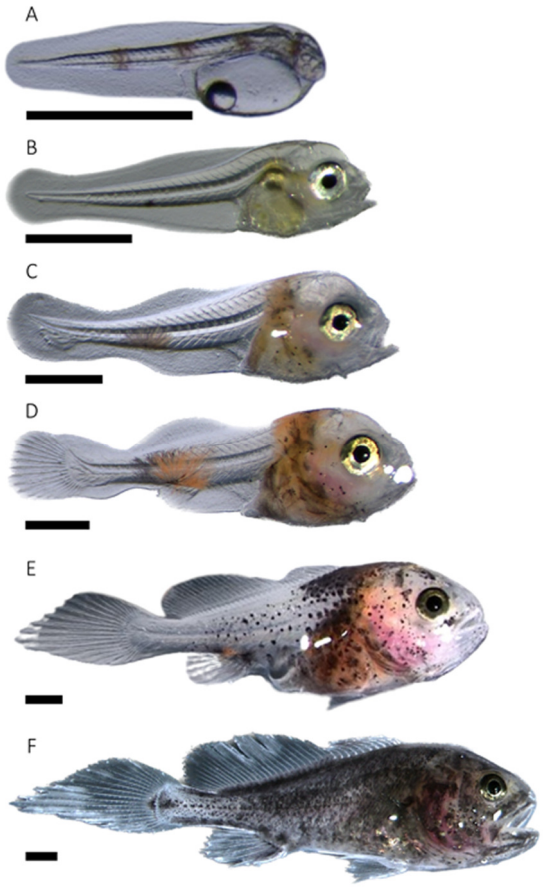


Figure 13. Larval development of *Protonibea diacanthus* at 35 ppt salinity and 30 °C water temperature. (A) 3 h post hatch larvae with body fully lengthened; (B) 5 days post hatch (dph) larvae pre-flexion; (C) 10 dph larvae beginning to undergo flexion; (D) 15 dph larvae beginning to display skin pigmentation around gills and gut cavity; (E) 20 dph larvae with fully developed caudal fin, more extensive skin pigmentation and beginning metamorphosis; (F) 23 dph completely metamorphosed juvenile. Scale bar for each stage = 1 mm. (Taylor et.al 2024)

4.3. Larval Rearing System

Key larval culture parameters are summarised in Appendix A, Table 2. Black jewfish larvae at the DAC are primarily reared in a 3500 L semi-recirculating intensive larval rearing system (Figure 14). The system is based on a commercial barramundi larval rearing design described by Schipp et al. (2007) and is housed within a temperature-controlled, biosecure hatchery room fitted with a footbath and hand sanitiser at the entry point.

The 3500L system is supplied with 1 µm filtered, UV-sterilised seawater delivered to a sump at an initial flow rate of 30 L/min, gradually increasing to 60 L/min by the completion of larval rearing. Water is recirculated from the sump through the larval rearing tank and returned to the sump, with exchange rates initially maintained at 12%/hour and progressively increased to 50%/hour as larval biomass and feeding rates increase.

Pure oxygen is supplied directly to the larval rearing tank to maintain oxygen saturation at approximately 100%. Surface skimmers constructed from PVC are used to remove surface oils and facilitate successful swim bladder inflation (Iwasaki et al., 2016 ; Friedmann and Shutty, 1999). Screens ranging from 60–500 µm are fitted to tank outlets to retain larvae and live feeds while allowing water and waste products to exit the system. Screen mesh size is increased progressively throughout larval development as fish size increases.

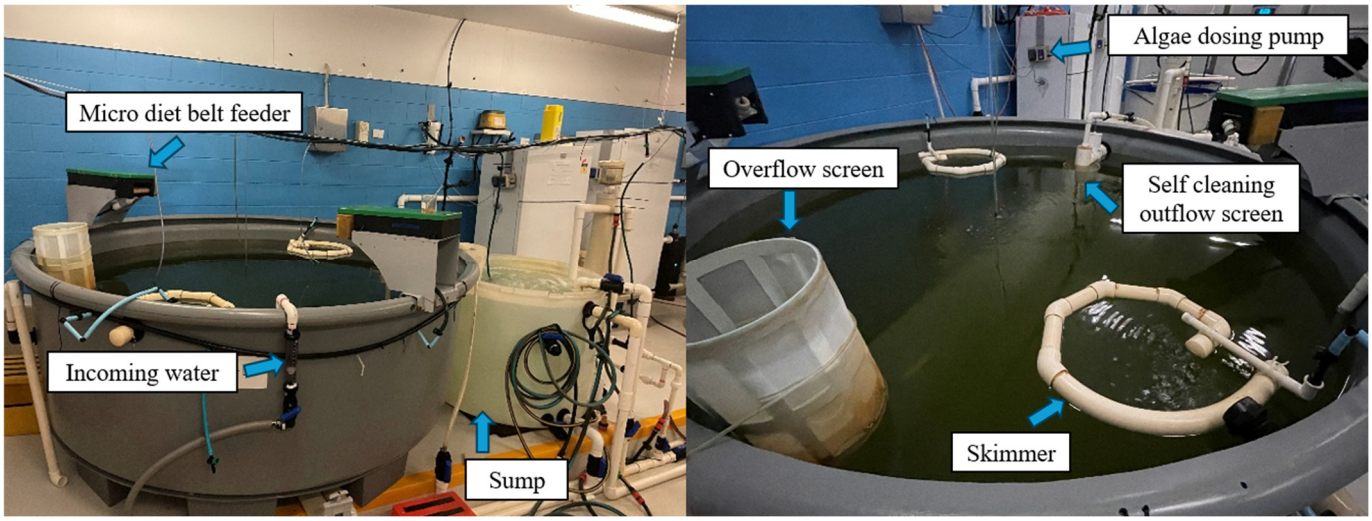


Figure 14. Finfish larval rearing system at the Darwin Aquaculture Centre, used for rearing cohorts of black jewfish *Protonibea diacanthus*. Images A and B denote technical components of the larval rearing system.

4.4. Water Quality

The water quality requirements of black jewfish larvae are similar to those of many tropical marine fish species. Optimal larval rearing conditions at the DAC include a water temperature of 29–31 °C, salinity of 31–36 ppt, pH of 7.8–8.1, total ammonia nitrogen (TAN) below 0.5 mg L^{-1} and dissolved oxygen between 5–7 mg L^{-1} (Taylor et al., 2024). Trials conducted at the DAC have shown that black jewfish larvae do not perform well at reduced salinities. Larvae reared at 12 ppt and 22 ppt exhibited swim bladder hyperinflation followed by increased mortality. Maintenance of these optimum water quality parameters is critical for achieving high larval survival, optimal growth and successful swim bladder inflation.

Water used for larval rearing is filtered to 1 µm and sterilised using ultraviolet (UV) treatment prior to entering the hatchery to minimise pathogen risks, particularly nodavirus. Water temperature is maintained

through temperature-control on the hatchery room itself and heat-chill units on the recirculating water system for the larval rearing tank where required. Dissolved oxygen is regulated through water exchange and the addition of compressed oxygen via oxygen diffusers, while salinity can be adjusted through the addition of freshwater if necessary.

As larval biomass increases throughout the rearing cycle, ammonia concentrations may rise and pH may decline. These changes are managed through increased water exchange rates, the addition of new filtered seawater and, where necessary, supplementation with dissolved sodium bicarbonate to buffer pH. Daily tank vacuuming following the introduction of microdiet is also important for removing uneaten feed and waste, helping to maintain dissolved oxygen, pH and TAN within acceptable ranges.

4.5. Feeding

Black jewfish larval rearing feeding regimes follow a typical progression of cultured live zooplankton and manufactured microdiet (Figure 15 and Appendix B). Black jewfish larvae readily consume and digest small strain rotifers (*Brachionus* sp.) at first feed from 2 dph. Black jewfish have a relatively large mouth gape and are likely capable of consuming large strain rotifers where available. Rotifers are stocked into the larval rearing tank system when larvae are 1 dph to allow rotifers to enrich with greenwater algae over multiple generations before first feeding. This greenwater is a 2:1 by volume mix of *Isochrysis* (Iso 1800, Reed Mariculture, California, USA) and *Nannochloropsis* (Nanno 3600, Reed Mariculture, California, USA) dosed into the tank continuously and maintaining an approximate total cell density of 500,000 cells mL^{-1}. Rotifer densities are maintained at 20-30 individuals mL^{-1}, and if additional rotifers need to be fed they can be added directly from rotifer production tanks.

Microdiet (Otohime, Marubeni Nisshin Feed Co. Ltd., Tokyo, Japan) is introduced to the larvae at 8 dph, prior to *Artemia*, beginning with small amounts of Otohime "A", and gradually incorporating and transitioning to sizes "B1" and "B2" at 10 dph and 16 dph, respectively.

Artemia are introduced from 11 dph, with instar I nauplii fed for one day before switching to feeding *Artemia* enriched with commercial lipid emulsions (S.presso, INVE or Algamate Gold, ADSI) from 12 dph until the end of larval rearing. Greenwater and rotifers can be removed from 17 dph once all fish are undergoing metamorphosis and are eating microdiet and *Artemia*, as at this stage rotifers no longer play a significant role in the diet. It is important to note that the days rotifers are removed and *Artemia* are introduced can vary depending on larval growth and development rates, and technicians regularly measure subsamples of larvae to ensure dietary changes are made at the developmental stages and sizes provided in this manual.

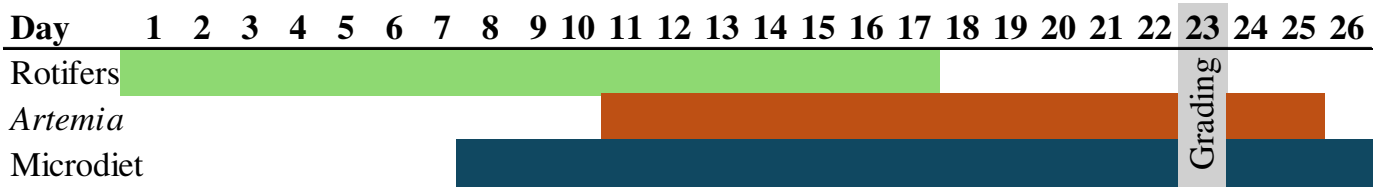


Figure 15. Larval rearing feeding schedule for farmed black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre.

4.6. Lighting

Hatchery light is an important abiotic factor when rearing larvae. Young pre-metamorphic larvae display signs of phototaxis and will scatter abruptly if subject to any sudden light increase and move towards any specific bright light sources such as torches. Red light or low light is used when observing black jewfish larvae to avoid creating additional stress or unnecessary energy expenditure by the larvae.

Light intensity during larval rearing at DAC has been typically maintained between 30 and 40 lux measured at the water surface. At this light level, all fish are able to see and consume live feeds from first feeding. Recent unpublished experiments conducted at the DAC on light intensity have shown improved larval growth and survival at higher lux levels (400 lux) up to 12 dph. However, in the later stages of larval rearing, higher survival was seen at lower light intensity (2 lux).

4.7. Grading and Handling

Black jewfish are typically ready to be graded out of the hatchery at 23 dph, once all fish are metamorphosed, typically with an average standard length of 13 mm (Figure 16). Light sedation with anaesthetic, such as AQUI-S or SED8 (Appendix E) is applied when handling and grading larvae out of the hatchery, to reduce the stress on fingerlings. The use of light anaesthesia reduces the numbers of moribund fish caused by handling, particularly in the early life stages.

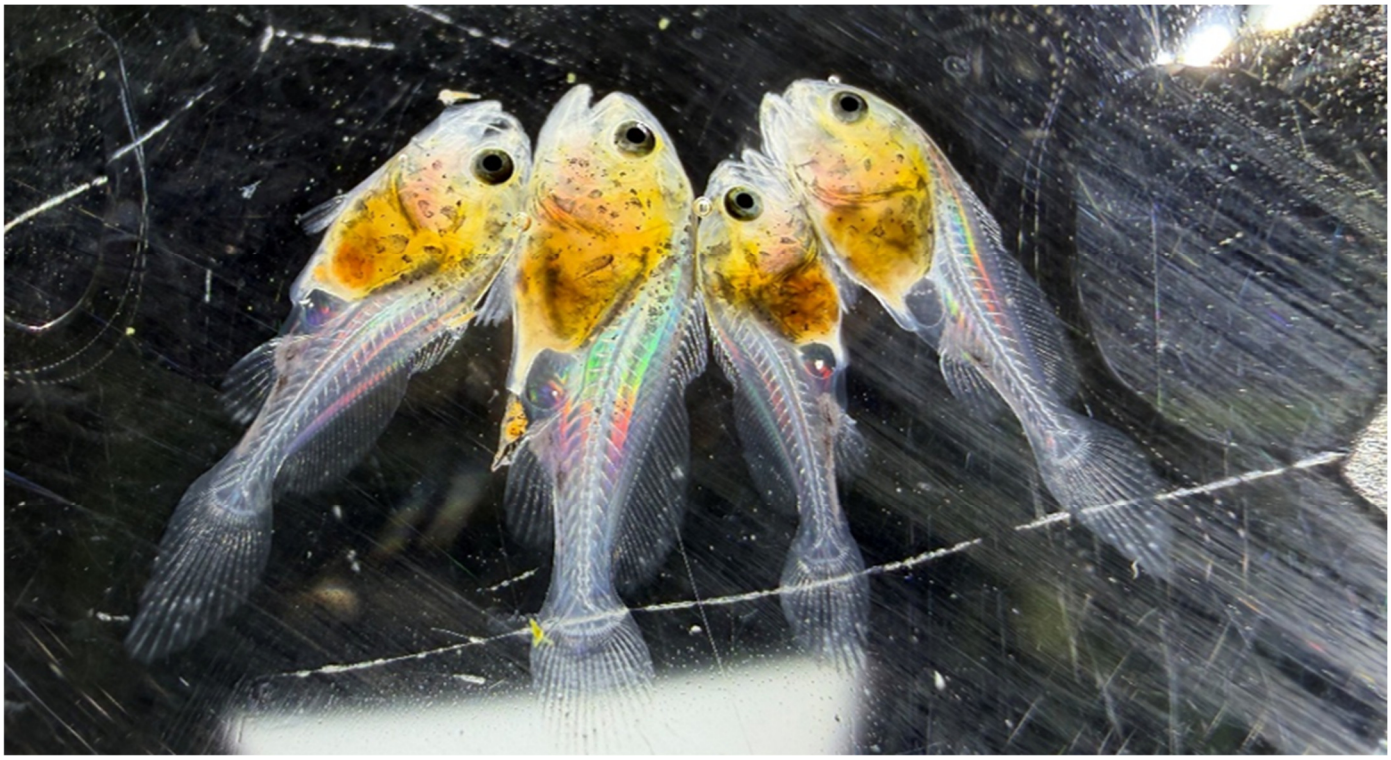


Figure 16. Juvenile farmed black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre, ready to grade out of larval rearing systems, immediately post metamorphosis. Image shows juveniles 13 mm standard length on a petri dish.

To move fish out of the hatchery, tank levels are dropped so staff can enter the tank, the fish are placed under light sedation (<5 ppm anaesthetic concentration) and gently captured in soft aquarium nets, placed in basins and poured into floating grading boxes, tanking care to minimise any time spent out of water. Fish are carefully graded as black jewfish tend to swim upward rather than downward through the grading bars (Figure 17A). Any fish sitting on top of a grade size can be netted with a soft aquarium net and either placed into another grade box or into a basin to go into a nursery tank for grow-out. Fish are counted using an electronic fish counter (Vaki Nano Counter) immediately following grading to estimate the number of juveniles transferred to nursery systems (Figure 17B).

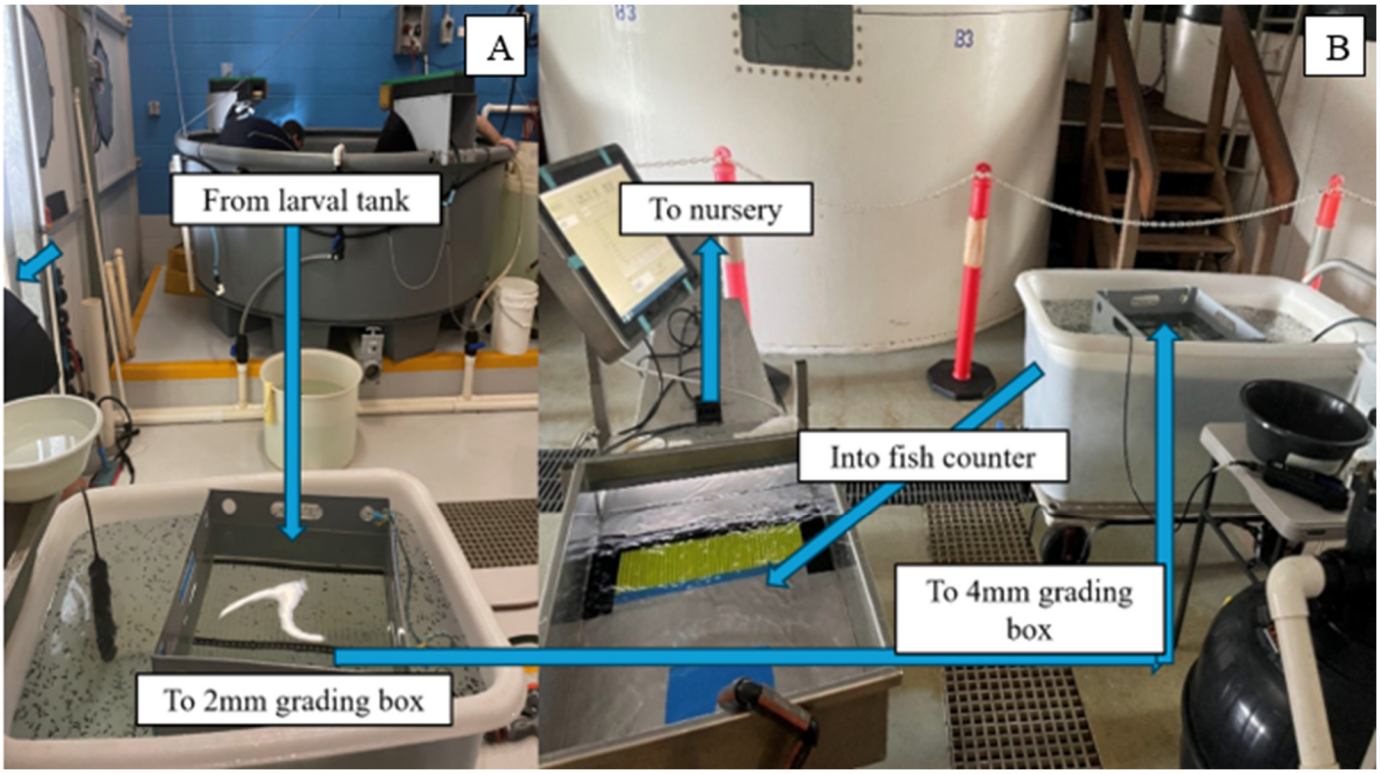


Figure 17. First grade and count of farmed black jewfish *Protonibea diacanthus* juveniles out of larval rearing tank at the Darwin Aquaculture Centre. Annotations and arrows denote workflow of fish movements from larval rearing tank into a 2mm grader box to separate the smallest fish inside the larval rearing room (A), then outside the room to a 4 mm grading box to separate the largest fish, counting in fish counter and transport to fish nursery systems (B). Both fish holding tubs and the larval rearing tank have oxygen monitoring probes to facilitate optimum dissolved oxygen control during the process.

5. Juveniles

A typical black jewfish hatchery runs at the DAC produces between 10,000 - 50,000 fingerlings, which can be grown to approximately 60 days old before sending to commercial farms for grow-out. Key juvenile culture parameters are summarised in Appendix A, Table 2. The culture methods in this section refer predominantly to these early juvenile culture stages. Additionally, a small number of fish from each run are usually kept at the DAC for on-growing and assessment for future broodstock.

5.1. Behaviour

Although black jewfish larvae inhabit all levels of the water column, juvenile fish shift to bottom dwelling behaviour after metamorphosis. This shift happens gradually over the first two weeks in juvenile rearing systems, resulting in entire populations of fish living in relatively stationary positions, equally spaced apart on the tank floor and facing into the tank's water current (Figure 18A). This stage represents a critical period for cannibalism mortality, as high stocking densities increase the incidence of tail-biting behaviour. Between 1-2 months of age, fish will begin constant swimming in both directions around the tank (Figure 18B). At this stage the fish are more robust and amenable to handling. In tank culture at the DAC, fish tend to stop actively swimming and aggregate together near the tank floor at approximately 3 months old, with this behaviour continuing into adulthood.



Figure 18. Early juvenile farmed black jewfish *Protonibea diacanthus* swimming behaviour at the Darwin Aquaculture Centre. Images depict juvenile fish A.) dwelling on the tank floor facing into the water flow at 57 days post hatch (dph) and B.) a proportion of the same population moving away from the tank floor to swimming laps around the tank, one day later.

Tail biting cannibalism occurs until fish are approximately 6 months old and is density dependent. Once fish are approximately 2 months old, tail biting is less likely to cause mortality, but can cause permanent damage to caudal fins, infections and impair swimming function (Figure 19). Juvenile black jewfish feeding behaviour is not vigorous, and fingerlings tend to consume food as it comes across them. More active feeding behaviour has been observed as fish become larger.



Figure 19. Visual representation of tail biting cannibalism effects on farmed black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre. Image shows A.) 30 day post hatch black jewfish after euthanasia due to cannibalism damage, B.) sub-adult black jewfish with permanent tail damage from tail biting in early juvenile stage, and C.) sub-adult black jewfish with no tail damage for reference.

5.2. Rearing Systems

Juvenile black jewfish have been reared in several different systems at the DAC and appear to perform best in almost flat bottomed, darker coloured, circular tanks with enough floor area to accommodate even spacing of fish on the tank floor during their bottom dwelling stage. Rearing juveniles in more steeply conical bottomed tanks has induced earlier onset of lap swimming behaviour, but also higher cannibalistic activity. Juveniles appear most 'comfortable' on a mostly flat-bottomed surface. However, the very low flow rates required in the two weeks following metamorphosis reduces effectiveness of the 'self-cleaning' function of these tanks, making daily tank vacuum cleaning laborious during this life stage.

Commercial nursery systems used at the DAC for black jewfish juveniles consist of 1000-10,000 L tanks, with flow though filtered seawater and screens at exit points. Water quality (DO, temperature, salinity and pH) is monitored twice daily for early juveniles, transitioning to once daily when they are in less dense grow-out systems.

A tank colour experiment at the DAC showed no difference in growth, survival or tail biting damage between fish reared in 120 L black, white, yellow, blue, green or red tanks. However, black jewfish grown at the DAC in larger commercial nursery tanks often display less tail biting aggression in black and dark green coloured tanks. Early-stage juveniles swim away from light sources, and darker environments may be favourable at this stage to reduce stress, although this has not yet been tested at the DAC.

5.3. Stocking

Stocking density plays a significant role in survival of black jewfish juveniles in early stages, due to their bottom-dwelling behaviour and tendency to establish territories on the tank floor. Stocking density is therefore considered in relation to available tank bottom surface area rather than tank volume alone. In the first month after metamorphosis in particular, fish are provided enough room for a 2 cm gap between them on the tank floor. At higher densities, juveniles are forced into closer proximity, increasing the incidence of tail-biting and cannibalism. Maintaining sufficient floor space for even distribution of fish can significantly reduce aggressive encounters and improve survival. As juveniles grow and swimming behaviours change, densities are adjusted through grading and redistribution into larger systems, to maintain welfare and growth.

5.4. Handling

Black jewfish juveniles are very susceptible to stress and display signs of shock when exposed to routine aquaculture operations such as netting, grading and tank cleaning. This has also been seen in response to sudden exposure to bright light, for example during transfer in buckets from one shaded growing area to another via short exposure to sunlight. They are particularly sensitive around approximately 30-45 dph, often displaying flared operculum and losing equilibrium, followed by increased mortality in the hours following the stress event (Figure 20). Handling black jewfish during these stages is kept to a minimum, with grading performed only when necessary, with increasing incidences of tail biting the key criteria to trigger a grading event. Stocking densities are kept low to reduce the need for reactive grading. Grading is conducted no more than once every 1-2 weeks. Once fish reach the schooling stage and start to swim around the tank between 50-60 dph, they are more robust to handling.

Light sedation with iso-eugenol emulsions (AQUI-S or SED-8; 5 ppm) is routinely used at the DAC during handling and grading of juvenile black jewfish to reduce handling stress. This practice was adopted following handling trials conducted on juveniles between 23 and 30 dph. In these trials, fish lightly sedated prior to netting, weigh-counting and grading experienced no mortality attributed to handling within the first 2 h following the handling event, whereas mortality was observed in unsedated fish exposed to the same procedures. During grading trials at 30 dph, the highest mortality occurred in larger fish that were graded without sedation, particularly when they underwent a second netting event. Affected fish typically displayed loss of equilibrium and flared opercula before death. Although overall mortality rates were relatively low, the losses were primarily larger, fast-growing juveniles and therefore have important production implications when handling commercial-scale numbers of fish. Light sedation also did not appear to adversely affect growth over the week following grading. These observations suggest that light sedation reduces the stress associated with netting and grading and provides a practical method for improving juvenile survival during routine husbandry procedures



Figure 20. Moribund 30 days post hatch (dph) black jewfish *Protonibea diacanthus* displaying signs of shock after handling during a grading event at the Darwin Aquaculture Centre.

5.5. Grading

Black jewfish are graded by capturing lightly sedated fish with a dip net and quickly transferring them into a basin filled with water from the tank. The basin is carried to a floating grading box (Figure 21) in the tank intended for the smaller size grade of juveniles.

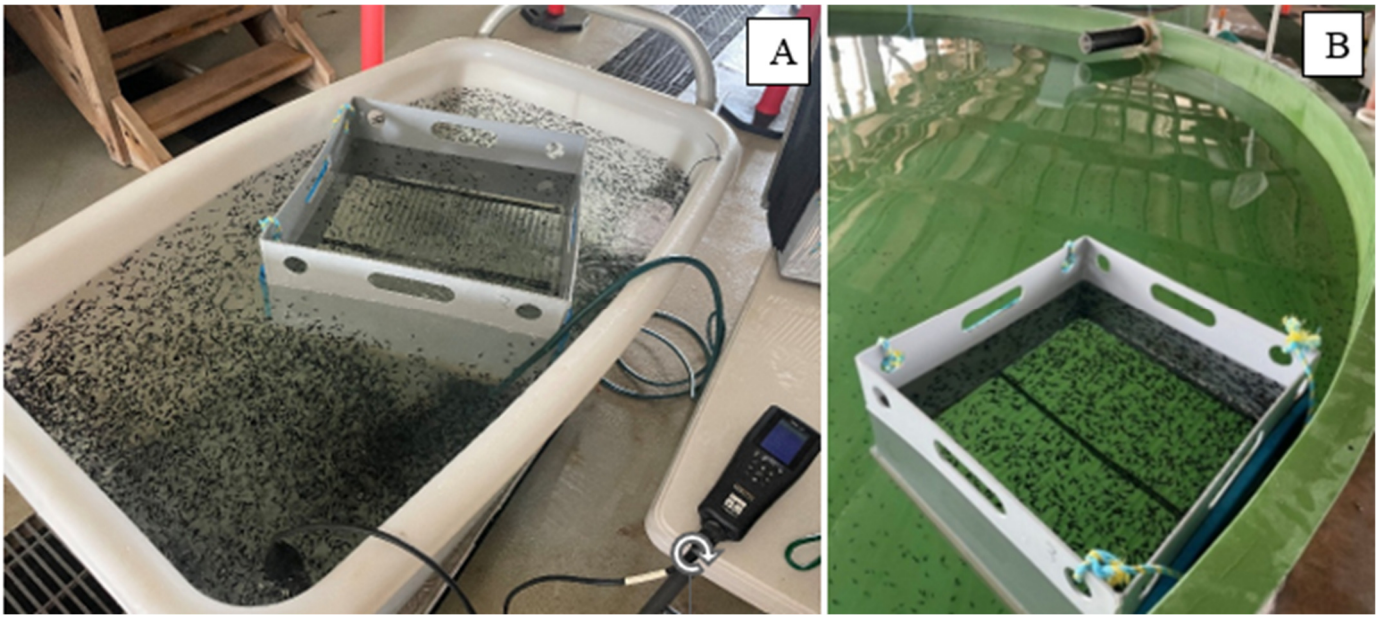


Figure 21. Grading black jewfish *Protonibea diacanthus* juveniles at the Darwin Aquaculture Centre. Image A shows fish in a transport tub after first grading out of larval rearing system, prior to being moved to nursery systems. Transport tub is fitted with compressed oxygen and monitored continually to ensure dissolved oxygen stays within optimal range (5.5-6.5 mg/L). Image B shows grading box with fish in a nursery tank system.

The grading process follows standard aquaculture grading procedures described by Schipp et al. (2007). Fish are gently released into the box; the smaller fish can swim down through the grader bars, and the box is gently lifted up and down in the water column to encourage fish to pass through the grader bars. Fish too large to pass through the bars are then netted back into the basin filled with water and moved to their

destination tank, either directly or via another grading box with larger bars to remove the largest size grade.

5.6. Feeding

Formulated microdiet (Otohime, Marubeni Nisshin Feed Co. Ltd., Tokyo, Japan) is the sole feed input for black jewfish juveniles once weaned from live *Artemia* at around 26 dph. Sinking or slow-sinking diets are most suitable due to the fishes' preference for occupying lower areas of the water column.

Juvenile black jewfish exhibit a relatively passive feeding response compared with other marine finfish species cultured at the DAC. Rather than actively pursuing feed, juveniles typically consume particles that drift past them in the water column. Feed is therefore distributed as evenly as possible throughout the tank to maximise feeding opportunities for all individuals.

Continuous belt feeders can be used to supply juveniles with microdiet over daylight hours; feeding activity appears minimal at night. Hand feeding is important in addition to belt feeders, especially in the first weeks after metamorphosis, to gauge feed response and ensure feeding is adequate to prevent cannibalism triggered by hunger. Care is taken to avoid overfeeding, as deteriorating water quality and the accumulation of uneaten feed require more frequent tank cleaning. This is particularly important in early juvenile stages, where handling and routine husbandry activities such as tank vacuuming may induce stress and mortality. However, some degree of feed wastage is often unavoidable because of the slow feeding behaviour of juvenile black jewfish and the tendency for feed particles to settle on the tank floor before being consumed. Juveniles will continue to forage on settled feed from the tank floor, but uneaten feed is removed before significant bacterial or fungal growth occurs. Under tropical rearing conditions at the DAC, feed remaining in tanks overnight can rapidly deteriorate and negatively affect both water quality and fish health. Regular tank cleaning and feed management are therefore critical components of juvenile husbandry.

5.7. Sampling and Measuring

Juvenile black jewfish at the DAC are sampled monthly during their first year of growth and every three months thereafter until approximately three years of age. During each sampling event, the lengths and weights of a representative sample of twenty fish are recorded to monitor growth performance and cohort health.

Prior to sampling, holding tanks are partially drained to facilitate fish capture. Juveniles and sub-adults less than 60 cm total length can generally be captured using dip nets and larger plastic nets (e.g. Environets), while larger fish should be restrained using a sling to minimise injury and scale loss. Light sedation is applied to the holding tank before capture to reduce handling stress. Captured fish are transferred to a dedicated sedation tank containing anaesthetic calculated for heavy sedation. The heavy sedation tank is aerated continuously, and dissolved oxygen should be monitored closely throughout the procedure (Appendix E).

Once heavily sedated, fish are weighed using laboratory scales. Smaller juveniles (<15 cm total length) are photographed on waterproof grid paper to allow subsequent length measurements from images (Figure 22), while larger juveniles and sub-adults are measured directly using a measuring board (Figure 23). All length and weight data is recorded immediately and entered into the facility sampling database following completion of the sampling event.

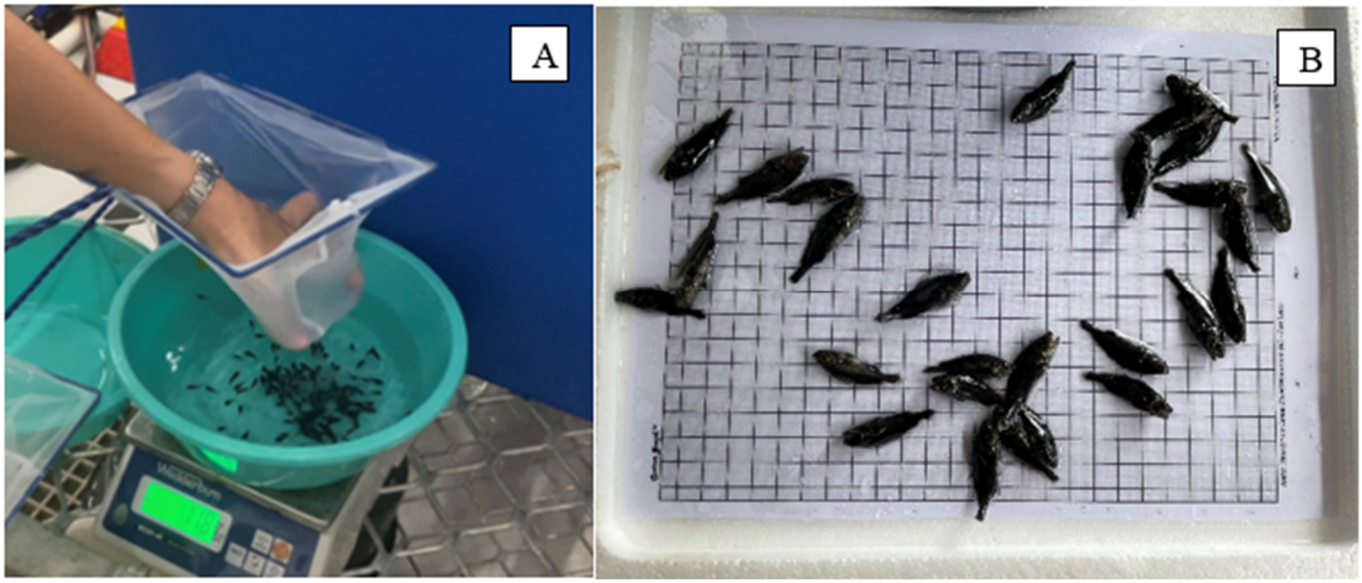


Figure 22. Sampling of farmed juvenile black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre. Images depict A) 23 days post hatch (dph) black jewfish being weighed on laboratory scales using a basin, and B) 55 dph black jewfish length measurement being measured on waterproof grid paper. A photo is taken of fish for later measurement, before returning fish quickly to the water.

Following measurement, fish are returned to clean seawater for recovery from anaesthesia. Larger individuals are supported gently, encouraging water ventilation over gills, until normal equilibrium and swimming behaviour return. Fish are monitored closely after release, and any signs of abnormal behaviour or prolonged recovery is recorded and investigated.

Once cohorts reach approximately two to three years of age, fish are generally transferred to broodstock populations and housed in larger systems. Routine growth sampling is typically discontinued at this stage, as fish become more susceptible to handling stress and monitoring within large broodstock tanks is technically more difficult. Thereafter, fish are generally only handled during reproductive conditioning and spawning assessments, as described in Chapter 3.



Figure 23. Sampling of farmed sub-adult black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre. Images depict A) black jewfish being weighed on laboratory scales using a basin, and B) black jewfish length measurement being taken using a measuring board.

5.8. Growth

Black jewfish are typically graded and moved from larval rearing systems into juvenile nursery systems at approximately 23 dph, when cohorts reach a mean standard length of approximately 13 mm. Following this point, growth rates generally increase as fish are weaned onto formulated diets, graded into uniform size classes and stocked at lower densities than those used during larval culture.

Growth rates can vary substantially between cohorts. Differences are likely related to variation in genetic variability, stocking density, water quality, temperature and feed regimes during various production trials at the DAC. Despite these variables, juveniles typically reach 50–60 mm standard length by approximately 55 dph under standard DAC production conditions (Figure 24).

Routine weighing of juvenile black jewfish prior to 55 dph is performed sparingly due to their sensitivity to handling during early developmental stages. Consequently, weight data collected during this period are generally obtained from opportunistic sampling events conducted for production monitoring and reporting purposes. Such measurements collected from four juvenile cohorts demonstrated substantial growth during the early nursery phase, with mean weights increasing from less than 1 g at 38 dph to over 5 g by 54 dph.

While growth trajectories differ between cohorts, black jewfish cultured at the DAC consistently demonstrate rapid growth during the early juvenile phase (0-1 year) when provided with appropriate nutrition, optimum water quality and stocking densities. Small numbers of fish on-grown at the DAC for use in future breeding programs have reached approximately 1 kg in the first year and approximately 3.6

kg at two years old. Maintaining low levels of handling stress, minimising cannibalism and ensuring adequate feed availability are particularly important for achieving optimal growth and survival during the first two months of culture.

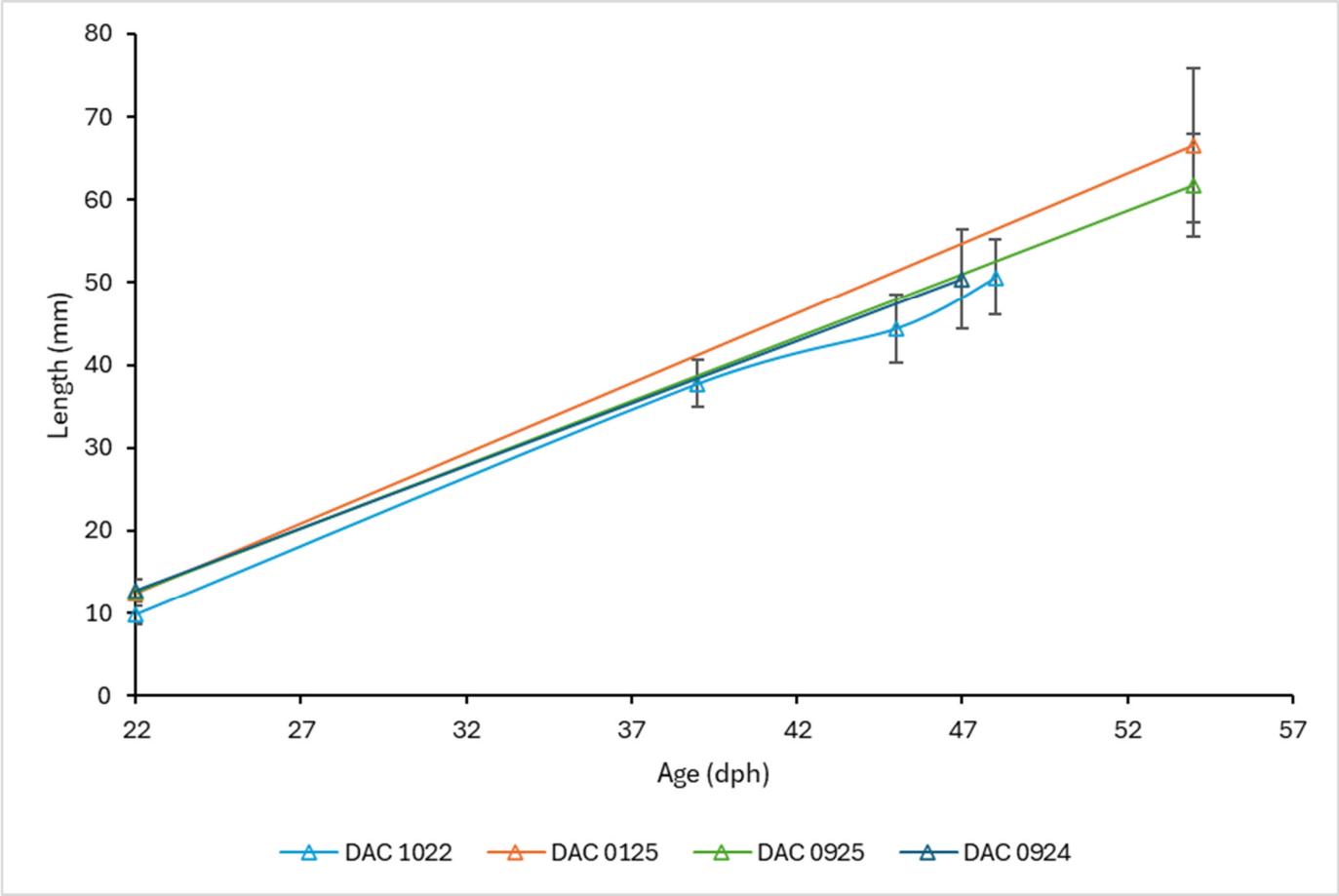


Figure 24. Line graph showing mean standard length (± 1 standard deviation) over the first 55 days post hatch (dph) of four black jewfish *Protonibea diacanthus* cohorts reared at the Darwin Aquaculture Centre. The four cohorts were grown between October 2022 and September 2025.

6. Challenges and Bottlenecks

6.1. Broodstock Capture and Handling

A significant challenge in black jewfish aquaculture production is collecting wild broodstock to establish a breeding population. Efforts to capture sexually mature broodstock over 1 m in length have been hampered by barotrauma and capture stress. Mortality rates of large broodstock are often 100% within 48 hrs of capture and transport to tanks.

The preferred method at the DAC is capturing wild juvenile black jewfish between 30-60 cm in shallower water, where survival rates are substantially higher. This creates significant lead times before fish reach sexual maturity. Capturing juvenile broodstock also increases costs, as hatcheries must invest labour and feed in growing fish before they can contribute to spawning.

6.2. Spawning

One of the most pressing bottlenecks in black jewfish production is securing consistent, high-quality spawns. Current protocols use single aqueous injections of LHRHa between 25-50 µg/kg body mass. Fish have been spawned in 15,000-45,000 L broodstock tanks and smaller 10,000 L shallow spawning tanks. Spawns have occurred around new and full moons with varying male:female ratios. Spawn quality has been inconsistent, with no clear trends among methods, and batches are often completely non-viable. Most non-viable eggs result from poor or absent fertilisation, but it remains unclear whether this is due to egg quality, sperm quality, or males and females spawning out of synchrony. Further research is required to develop reliable commercial spawning protocols.

6.3. Cannibalism

One of the most damaging phases of black jewfish aquaculture is cannibalism by post-metamorphic juveniles during early nursery production. Cannibalism is characterised by "tail biting", where the caudal fin is damaged and, in severe cases, removed, exposing the posterior spine. Such damage can affect 100% of tank individuals, increasing mortality and causing permanent deformities when fins cannot regenerate. High stocking densities appear to exacerbate cannibalism by increasing interactions among fish. Identifying methods, beyond reactive grading, to reduce cannibalistic behaviour will significantly improve fingerling quality for grow-out.

6.4. Grow-out

Grow-out of black jewfish has largely been carried out on commercial pond-based aquaculture farms. Unfortunately, parasite and disease outbreaks have so far impeded the ability of farmers to grow fish out to harvest for sale, presenting significant risk to prospective farmers. Research into optimal feeding rates, nutrition and disease management will assist the grow-out of black jewfish on a commercial scale.

7. Future Research Recommendations

Primary bottlenecks restricting the commercialisation of black jewfish aquaculture in northern Australia are the development of reliable broodstock spawning protocols and the management of tail-biting aggression during the juvenile rearing phase. Addressing these challenges should be prioritised in future research programs, as they currently constrain consistent juvenile production and survival.

In parallel, a comprehensive biochemical and market assessment of farmed black jewfish swim bladders, compared with wild-caught product, is required to determine the potential market value and economic viability of black jewfish aquaculture in a northern Australian context. Such information would guide farmers towards the feasibility and economic appeal of developing black jewfish aquaculture as an industry.

To fully evaluate the commercial potential of the species, research should also focus on refining grow-out protocols from juvenile stages through to commercially significant numbers at market size. An accurate understanding of the marketability of black jewfish as a farmed product relies on consistent production of fish to market size, a goal which has not been achieved to date.

This combination of reproductive, on-growing and market-focused research will be essential for progressing black jewfish from an emerging aquaculture candidate to a commercially scalable industry in northern Australia.

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9. Appendices

Appendix A: Summary of best practice black jewfish *Protonibea diacanthus* culture parameters at the Darwin Aquaculture Centre

Table 1. Best practice parameters used at the Darwin Aquaculture Centre for black jewfish *Protonibea diacanthus* broodstock husbandry.

Life Stage	Parameter	Acceptable Range	Additional notes
Broodstock care	Temperature (°C)	25-32	Ambient water temperatures fluctuate with season
	Salinity (ppt)	10-33	Salinity can be lowered to reduce parasite load or stress
	Dissolved oxygen (mg/L)	5-7	Optimal 6mg/L and 100% saturation
	Stocking density (kg/m³)	2-7	
	Feeding rate (% BW)	3-5	Fed frozen squid, fish, prawns and INVE Breed M pellets, 3 x weekly
	Photoperiod	12:12	Ambient photoperiod in Darwin is between 11-13h daylight annually
Broodstock spawning	Temperature (°C)	30-31	Optimal spawning period is in summer months
	Salinity (ppt)	29-32	Salinity fluctuates due to wet season rainfall
	Broodstock weight (kg)	5-20	
	AQUI-S sedation dosage	15-30	Heavy sedation for cannulation and injection, light sedation only required for injection alone
	LHRHa dosage (µg/kg BW)	50	Intramuscular saline injection of LHRHa, same dosage for males and females
	Fecundity (eggs/spawn)	1-3 million	Approximate number of eggs released per female, with larger spawns from larger females
	Fertilisation rate (%)	10-95%	Wide variation seen between spawns due to unknown factors
	Time to hatch (h)	12	Hatch time is slower in cooler temperatures

Table 2. Best practice parameters used at the Darwin Aquaculture Centre for black jewfish *Protonibea diacanthus* larval early and juvenile rearing.

Life Stage	Parameter	Acceptable Range	Additional notes
Larval Rearing	Temperature (°C)	28-31	Temperature controlled larval rearing system used to match ambient spawning temperature
	Salinity (ppt)	28-33	Salinity fluctuates due to wet season rainfall, lower salinities outside this range not optimal for larvae
	Dissolved oxygen (mg/L)	5.5-6.5	Optimal 6mg/L and 100% saturation
	Greenwater (cells/ml)	500 000	Reed Mariculture Iso 1800 and Nanno paste 2:1 ratio during rotifer feeding only
	Rotifer density (ind./mL)	10-30	Optimal 20 small strain rotifers/ml from 1-18 days post hatch
	Artemia feeding (dph)	11-25	Fed in 1-3 batches/day from tail flexion until after metamorphosis, amounts are stocking dependant
	Microdiet feeding (dph)	8+	Commence microdiet introduction from day 8
	Light intensity (lux)	2-400	400 lux from day 1- 10, then 20 lux from day 11- metamorphosis
	Stocking density	<70/L	
	Time to metamorphosis (days)	23	Metamorphosis usually complete after fish have reached 13mm standard length
	Water exchange (%/h)	12-30	Exchange increases during larval rearing, with pH drop the trigger to increase
	Expected survival	1-30%	
Early Juvenile Rearing	Temperature (°C)	25-32	Ambient water temperatures fluctuate with season
	Salinity (ppt)	10-33	Salinity drops after wet season rainfall to 28ppt, and can be lowered manually to control skin infections
	Dissolved oxygen (mg/L)	5-7	Optimal 6mg/L and 100% saturation
	Stocking density	1-2cm apart	Early stage stocking density based on floor surface area as juveniles sit on the bottom
	AQUI-S sedation	light	Light sedation used for handling events to reduce stress related mortality
	Feeding frequency	continuous	Continuous or at 1 hourly intervals, daylight hours only

Appendix B: Larval rearing standard operating procedures schedule for black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre

Table 3. Standard operating schedule for larval rearing of black jewfish, *Protonibea diacanthus* at the Darwin Aquaculture Centre.

Age (days)	Greenwater T.iso: Nanno	Rotifers /ml	Enriched *Artemia* (million) Feed AM	Feed PM	Artificial Feed Otohime (g) A	B1	B2	C1	Total	Water % daily new water	exchange	Activity/Development
-2												Spawn induction
-1												Ozone eggs
0												Hatching
1	400Ti 200N	10										Stocking and first feeding
2	400Ti 200N	20										Swim bladder inflation
3	450Ti 225N	20										
4	450Ti 225N	20										
5	450Ti 225N	20			*Microdiet feed amounts are a guide only, adjust as needed*							
6	450Ti 225N	20										
7	450Ti 225N	20										
8	500Ti 250N	20	*Artemia feed amounts are a guide only, adjust as needed*		5				5			First microdiet feed
9	500Ti 250N	20			25				25			Commence daily tank vacuuming
10	500Ti 250N	20			40	10			50			Tail flexion onset
11	500Ti 250N	20	1 (nauplii)		50	25			75			First *Artemia* feed, delay if tail flexion is not yet underway
12	500Ti 250N	20	1		50	50			100			
13	500Ti 250N	20	2	2	50	75			125			
14	500Ti 250N	20	3	3		150			150			
15	500Ti 250N	20	4	4		175			175			Cannibalism onset
16	500Ti 250N	20	4	4		150	50		200			Increase *Artemia* feeding to 3 daily feeds to mitigate cannibalism if needed
17	500Ti 250N	20	5	5		150	75		225			
18	500Ti 250N	20	6	6		150	100		250			
19			7	7		150	125		275			Early *Artemia* feed once rotifers gone
20			6	6		150	150		300			Start to space out *Artemia* feeds to encourage microdiet weaning
21			5	5		150	175		325			
22			4	4		125	225		350			Metamorphosis complete
23			3	3		100	275		375			First grade
24			2	2		50	300	50	400			Fish in nursery systems
25			1				300	100	400			

Appendix C: Daily broodstock fish observation checklist for black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre

Date	Biomass (kg)	Water Qualities						Feeding					Comments (feeding/health /unusual behaviour)	Tech
		Daily				Weekly								
		Temp (°C)	DO (mg/L)	Salinity (ppt)	pH	TAN (mg/L)	Nitrite (mg/L)	Bait Fish (kg)	Breed M (kg)	Defrosted (kg)	Total eaten (kg)	Vitamins		

Figure 25. Daily record sheet for water quality monitoring and feeding rates of black jewfish broodstock, *Protonibea diacanthus*, at the Darwin Aquaculture Centre.

Appendix D: Ectoparasite treatment record sheet for black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre

Black jewfish treatment record sheet			
Date:		Tech:	
Treatment:		Time in:	Time out:
Tank:		Amount:	
Dosage:		Duration:	
Pre WQ		**WQ 45mins**	
DO		DO	
Temp		Temp	
Salinity		Salinity	
pH		pH	
WQ 15mins		**WQ 60mins**	
DO		DO	
Temp		Temp	
Salinity		Salinity	
pH		pH	
WQ 30mins		**Post WQ**	
DO		DO	
Temp		Temp	
Salinity		Salinity	
pH		pH	
Observations			

Figure 26. Record sheet for chemical treatments used on black jewfish, *Protonibea diacanthus*, at the Darwin Aquaculture Centre as part of disease management regimes.

Appendix E: Sedation dosage table for use of iso-eugenol for black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre

Table 4. Light and heavy sedation dosage and usage for iso-eugenol based anaesthetic (540g/L) for juvenile and adult black jewfish, *Protonibea diacanthus*, at the Darwin Aquaculture Centre.

Levels of Sedation using iso-eugenol based anaesthetic (540g/L) for black jewfish			
Level	**Dosage**	**Use**	**Signs**
Light	5ppm	Weighing, moving, health checks	• Partial loss of equilibrium • Slowed respiration • Minimal response to stimuli
Heavy	15 ppm 0-3 years 30ppm 3 years+	Cannulation or injection	• Complete loss of equilibrium • No response to external stimuli • Minimal movement of operculum and fins
Euthanasia	40ppm	Culling or euthanising for specific requirement	• No movement of operculum observed for 60 seconds. To be followed up with cutting of gill arches or blow to the head.

Appendix F: Gonad biopsy and spawn induction record sheet for black jewfish *Protonibea diacanthus* at the Darwin Aquaculture Centre

Maturation assessment and spawn induction of black jewfish								
Date:				**Tech:**				
Fish no.	**Wild/ Farmed**	**Tank**	**Time under 30ppm anaesthesia (min)**	**Sex (M/F)**	**Reproductive status (oocyte size/ sperm activity)**	**Weight (kg)**	**Length (cm)**	**Volume hormone injected (ml)**
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								

Figure 27. Maturation assessment and spawn induction record sheet for black jewfish, *Protonibea diacanthus*, at the Darwin Aquaculture Centre.