Technical advice on containment of tetraploid Pacific oysters (*Crassostrea gigas*)

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Work area/ requested by	Fisheries NZ - Aquaculture Unit

Review Steps	**Name**	**Date of signoff**
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Technical advice on: Containment of tetraploid Pacific oysters (*Crassostrea gigas*)

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Purpose of document

To provide Fisheries NZ (Aquaculture Unit) with technical advice to inform establishment of an MPI position on physical containment of tetraploid Pacific oysters (*Crassostrea gigas*).

Executive Summary

The Pacific oyster is an accidental introduction to New Zealand (first recorded in 1971), and has since become a commercially farmed species for which wild populations are an important source of spat for aquaculture stock propagation. This assessment addresses the potential impacts that tetraploid Pacific oysters held in New Zealand open waters could have on wild (diploid) populations of the species.

The potential mechanisms of impact are competition and fertilisation interference. Both of these mechanisms are driven by organism fitness—if tetraploids have greater growth, survival and reproduction, they could establish local populations and outcompete diploids for resources. Established tetraploid populations could also breed with wild diploids, producing sterile offspring and reducing diploid spawning success.

Currently available information indicates that the reproductive performance of tetraploid Pacific oysters is substantially lower than that of diploids. The potential for uncontained tetraploid Pacific oysters to establish in New Zealand open waters and impact upon wild diploid populations is therefore considered unlikely.

Background

Moana New Zealand are investigating product development opportunities for Pacific oyster aquaculture, and have approached Fisheries NZ (Aquaculture Unit) seeking a formal MPI position on physical containment of tetraploid Pacific oysters. Biosecurity Science and Risk Assessment were asked to provide technical advice on this topic, which Fisheries NZ will use to inform MPI's formal position.

Analysis

Polyploid oyster aquaculture

In some commercial oyster aquaculture operations, tetraploid broodstock (individuals with four sets of chromosomes) are mated with normal diploid stock (two sets of chromosomes) to produce triploid offspring (three sets of chromosomes). Triploid oysters are sterile, and the energy that would have gone to gonad maturation and spawning is instead directed towards growth (Nell 2002). Aquaculture of triploid oysters is a growing international industry (Dégremont *et al.* 2012; Wadsworth *et al.* 2019), as triploid oysters have superior yields and meat condition than diploids.

Historically, commercial triploid oyster spat has been produced in laboratories via chemical, thermal, and/or pressure treatments of gametes (Nell 2002). None of these treatments can induce 100% triploidy and complete sterility, which can only be achieved by crossing tetraploid and diploid oysters (Nell 2002). Given this limitation, the development and use of tetraploid oyster broodstock for triploid spat production has become a widespread industry practice (Matt & Allen 2014). First-generation tetraploid oysters are produced in laboratories and are fertile, and subsequent generations are produced from tetraploid × tetraploid matings (Matt & Allen 2014). Commercial quantities of triploid spat are produced by crossing tetraploid males with diploid females (Matt & Allen 2014), however this approach has yet to be used in New Zealand.

Tetraploid oyster biosecurity

With few exceptions, tetraploids are held in open (coastal) waters for the purposes of broodstock propagation, stock improvement research and seed production. Countries that have open water tetraploid broodstock include Australia, Chile, China, Ireland, Mexico, South Korea, Vietnam and the United States (but see below) (Allen 2017).

Tetraploid broodstock in France and the U.S. state of South Carolina are required to be held in containment because of concerns about potential impacts on wild populations of *Crassostrea gigas* and *C. virginica*, respectively (Dolmer *et al.* 2014, Allen 2017). In open waters, uncontrolled tetraploid breeding could result in the establishment of a “wild” tetraploid population (Allen 2017). If tetraploids have greater fitness (i.e., growth, survival, reproduction) than diploids, competition with introduced tetraploids could have a negative impact upon local (diploid) oyster populations.

If tetraploid and wild (diploid) oysters were to breed with each other in open waters, this would produce “wild” triploids. This is a demographic dead end for diploid populations, as a proportion of the reproductive effort becomes directed towards producing sterile offspring. Tetraploid × diploid matings could therefore reduce wild (diploid) oyster reproductive output (Allen 2017).

The biosecurity implications of tetraploid oyster aquaculture haven’t been researched. The only information available on this topic is a summary report of a biosecurity workshop on tetraploid *Crassostrea virginica*, held at the Virginia Institute of Marine Science (VIMS) in November 2017 (Allen 2017). The lack of research on this topic has been attributed to the limited availability of tetraploid stocks, which have been restricted to industry use (S. Allen, pers. comm., 26 July 2019).

Diploid vs. tetraploid fitness: survival and reproduction

Information on the performance of tetraploid oysters comes from *C. virginica* hatchery programmes in the eastern United States (Eastern Seaboard and Gulf Coast). The collective experience of tetraploid oyster producers suggests that compared to diploids, tetraploids are inferior (Allen 2017):

- Development to sexual maturity takes longer
- Gametes are abnormal (fragile eggs; large, slow and less mobile sperm)
- Sperm densities required for successful fertilisation are far higher
- Field survival of adults is often low
- Overall fecundity is lower

While these various performance descriptors (e.g., “longer”, “far higher”, “low”) haven’t been formally quantified (but see below), they represent the prevailing view among eastern US tetraploid hatchery programmes.

Hatchery data from VIMS demonstrate that tetraploids have lower fecundity, and a larval survival rate ten times lower than that of diploids (Table 1).

Table 1. Diploid vs. tetraploid reproductive performance of hatchery *Crassostrea virginica* – mean values calculated over an 8-year period (2010–2017). Adapted from Allen (2017).

	Tetraploid	**Diploid**
Fecundity (million eggs/individual)	2.11	6.3
Hatch rate (%)	16.4	37.8
Survival to eyed larvae (pediveliger) (%)	14.4	68.6
Set rate (%)	20.5	18.8
Egg to spat (%)	0.41	4.7

Husbandry of tetraploid *Crassostrea gigas* in New Zealand

Moana New Zealand have indicated they plan to propagate tetraploid stock by strip spawning (E. Malpot, pers. comm., 30 August 2019). Under this approach, stock are typically transferred from the open water to a hatchery conditioning system, which is a controlled environment for oyster "ripening", i.e., inducing and regulating gonadal development (Meritt 2003). Upon the development of mature gametes, the stock is shucked and the gonads are collected. The harvested sperm and eggs are then used for hatchery spawning of triploid stock and subsequent tetraploid generations.

Likelihood of tetraploid *Crassostrea gigas* establishing in New Zealand open waters

Currently available information suggests that deployment of tetraploid *Crassostrea gigas* in New Zealand open waters is unlikely to lead to the establishment of feral tetraploid populations:

- In theory, the strip spawning approach means that stock will be removed from open waters before uncontrolled natural spawning could occur.
- If stock undergoes an uncontrolled natural spawn, the poor reproductive performance of tetraploids (e.g., gamete abnormalities, low fecundity, reduced larval survival) makes it unlikely that a viable population will eventuate.
- If local populations of *C. gigas* spawn concurrently with tetraploids, the high density of diploid gametes will impede tetraploid × tetraploid fertilisation.

This likelihood assessment is based on three assumptions:

1. **Tetraploid *C. gigas* will be removed from open waters before they reach spawning condition.**
2. **The reproductive performance of tetraploid *Crassostrea virginica* is representative of tetraploid *C. gigas* performance.** Data on *C. virginica* are likely to be a valid proxy for *C. gigas*, as poor reproductive performance has been a consistent issue in the development of tetraploid aquaculture broodstock (Piferrer *et al.* 2009).
3. **Tetraploid *C. gigas* stock will be sourced solely from New Zealand.** If imported seed/gametes are used for broodstock improvement, it is advised that containment conditions be reviewed to ensure that appropriate biosecurity measures are in place to prevent genetic introgression with local *C. gigas* populations.

Broodstock reproductive performance can improve over time/domestication, therefore it is advised that containment conditions be re-evaluated as data on the performance of New Zealand tetraploid *C. gigas* become available.

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