Red King Crab: Managing an Invasive Species

by Synne Johnsen, Abbey Lewis, Ainslie Nash, Marcelle Oliveira, Alfonso Parrado & Ingvild Veland

Invasive species are species that have moved into a location they are not native to. They have a tendency to spread and can potentially alter the environment, economy, or human health in various ways (Carroll, 2011; Falk-Petersen et al., 2011). Public opinion on invasive species is generally negative, with the pervasive assumption that these organisms can only be detrimental to the ecosystems they invade (Readfearn, 2019). However, scientific opinion is beginning to shift to the idea that these species can sometimes be beneficial.

Even endemic species can be harmful to the overall health of an ecosystem. For instance, *Anopeheles* mosquitoes are a malaria vector endemic to many regions in Africa that could be replaced or removed in an environmentally-sound manner (Alphey et al., 2010). Moreover, invasive species can occasionally benefit ecosystems. Overfishing in New England reduced the population of predatory fish that fed on native purple marsh crabs, allowing the crabs to over-graze the young shoots of cord grass. Invasive green crabs took-over the niche of these fish, effectively controlling the population of purple marsh crabs and restoring balance to the ecosystem (Bertness & Coverdale, 2013). Of course, invasive species can have very negative effects on ecosystems as well, such as the Asian tiger mosquitoes and their expansion from their native SE Asian home to around the entire world (Juliano et al., 2005).

As global warming forces many endemic species to shift their range (Bellard et al., 2018), it's important to evaluate current cases of successful invasive species management. An excellent example is the red king crab (*Paralithodes camtscaticus*; henceforth referred to as RKC). RKCs are native to the North Pacific Ocean but introduced to the Barents Sea via Russia's Murman fjord in the 1960s to establish a new fishing resource (Hauge, 2010). It took approximately 15 years for RKCs to migrate and establish along the northern coast of Norway, and they are not stopping (Hauge, 2010).

Today, RKCs significantly impact the Norwegian economy and marine habitats. While invasive species like RKCs can pose major problems, how feasible is it to try and halt or reverse its invasion? Is it more efficient to try and manage it instead? This paper will analyze the controlment of RKCs in Norway, and how these management strategies could be extended to future cases of invasive species.

The RKC is a highly valued delicacy on the international market and currently makes a significant contribution to the income from fisheries in the region (Falk-Petersen et al., 2011). Since the first commercial harvest of RKCs in 2002, the Norwegian seafood industry has developed new technology and knowledge for handling these species. This includes new fishing gear, conditions for live storage and processing, handling of by-products, and entrance into new markets. In 2016, Norwegian export of RKCs amounted to 529 million Norwegian Kroner (Lorentzen et al., 2018). RKCs are especially lucrative because their meat has a delightful taste (Lorentzen et al., 2018).

Since the commercial harvesting of RKCs represents a significant source of income for the Norwegian seafood industry, it is strongly connected to SDGs 8 and 12, representing economic growth and responsible consumption & production. Their presence supplements the economy, but its important to aim for sustainable economic growth and fishing.

Though invasive in both Russian and Norwegian waters, RKCs have a unique impact on Norway's northern oceans because of differing topographies. Russia has shallower coastal waters, where RKCs must travel longer distances to reach winter feeding depths. This shallow coast allows RKCs to spread out more than in Norway, where both shallow and deep water can be found near the fjord coastline.

Norwegian RKCs thus concentrate in larger groups, inflicting more intense damage to bottom sediments (Hauge,2010).

RKCs impact northern Norwegian marine ecosystems in several ways. Significantly lower biomass and abundance of Barents Sea benthic organisms was found in samples between the 1990s and 2007, alongside a notable absence of larger specimens (Sundet, 2014). Oug et al. (2011) also found significant reductions in soft sediment fauna living in RKC-invaded areas of Varangerfjorden. Their presence has degraded sediment quality in Varangerfjorden and other northern Norwegian waters because they feed on organisms who perform important environmental functions, like bioirrigation, resulting in hypoxic seabeds (Oug et al., 2011; Sundet, 2014). Mikkelsen and Pedersen (2012) found that RKCs in Varangerfjorden impact pelagic organisms too, because they consume a mass of lumpsucker eggs equivalent to 1/3 the annual commercial catch, which could negatively impact recruitment. Finally, RKCs can also dominate ecosystems. Since RKCs are adaptable, have large populations and can easily disperse, they have significantly altered the structure of some fjord ecosystems, like in the waters off Várjat and Porsángu, past a point of no return (Broderstad & Ethyorson, 2014). This includes reducing native species diversity within communities, which could impact their efficiency, production and function as an ecosystem (Oug et al., 2011).

The power of these crabs to alter an ecosystem relates to SDG14, life below water. It specifically impacts targets 14.2 and 14.5 that involve sustainably managing and protecting marine and coastal ecosystems to avoid significant adverse impacts and conserving at least 10% of coastal and marine areas, respectively. Although the Norwegian government considers RKCs to be an invasive species, given its huge economic benefits, the species is also considered worth protecting in the areas it has established in today. The conservation of RKCs was a collaborative project between Norwegian and Russian governments up until 2007, when they agreed to individually manage the species (Fiskeri- og kystdepartementet, 2007, p. 21-22).

When considering the management strategies for RKCs one has a wide range of opinions and variables to consider before coming forward with a definitive answer. Complete eradication of the animal would be undesirable for many people in the region. Furthermore, eradication methods, though often touted, are usually costly and ineffective (Carroll, 2011; Falk-Petersen et al., 2011; Wallach et al., 2015).

In order to implement an effective management strategy, ecologists must understand certain factors at work in the environment such as: the evolutionary resistance of native species to competition; the lifecycle of the invasive species and abiotic factors that are similar or different to the invasive species native habitat such as temperature and topography (Carroll 2011; Falk-Petersen et al., 2011). In the case of RKCs, further investigation into the larval and post-larval life stages needs to take place and competition and predation effects on their population (Falk-Petersen et al., 2011).

Currently, the Norwegian government has sought to address both the ecological concerns and the economic potential of RKCs. Due to the Russian government's stand that RKCs are an economic resource to be managed, complete eradication is impossible as there will always be expansion into Norwegian waters (Sundet & Hoel, 2016). As such, the Norwegian government has implemented an open access fishery west of 26°E, which has so far delayed the further westward expansion of RKCs, and introduced a quota based fishing area east of this point in order to maintain a sustainable fishing resource for the local communities (Sundet & Hoel, 2016).

Human induced population limitation is not the only strategy available for managing ecosystems. Apex predators provide a valuable top down pressure on ecosystems to balance the bottom up, or resource limitation pressures (Carroll, 2011; Wallach et al., 2015). By maintaining a healthy and diverse ecosystem you can increase the resilience of native species to the threat posed by invasive species and create the conditions that would allow coexistence to occur. In the case of RKCs, this would mean cultivating a favourable habitat for marine mammals and large predatory fish, such as cod (Falk-Petersen et al., 2011).

In conclusion, one could assert that the combination of both anthropogenic pressure and ecosystem resilience is the most effective method of minimising the damaging and maximising the gains from invasive species.

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