MCCIP Marine Climate Change Impacts Partnership

2018

Climate change and marine conservation

Supporting management in a changing environment

Sandeels and their availability as seabird prey

- Sandeels are an important trophic link between plankton and predatory fish, seabirds and mammals, and support a large fishery in the North Sea.
- Seabirds are particularly sensitive to sandeel availability because they depend on them to feed their chicks.
- Climate change can have a direct impact on the reproductive timing of sandeels and the phenology of the plankton prey they depend on, increasing the likelihood of a mismatch between sandeel larvae and their prey, leading to poor recruitment.
- Current approaches to managing sandeels include population level landing restrictions and closed areas. However, further restrictions on anthropogenic activities in seabird foraging areas could be considered. The growing contribution of alternative prey such as sprat requires that fisheries on forage species should take account of predator requirements.

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Sandeels

Raitt's sandeel, *Ammodytes marinus* is the most important sandeel in the north-east Atlantic, being a key trophic link between zooplankton and many piscivorous fish, seabirds and mammals, as well as supporting a large industrial fishery in the North Sea.

While surface feeding seabirds such as black-legged kittiwake and Arctic tern appear particularly sensitive to sandeel availability, many other species including puffin, guillemot, razorbill and shag depend on sandeels to feed their chicks.

Major seabird breeding failures in the Northern Isles, Faroe Islands, Iceland and off the north-east UK[1] are linked to declines in sandeels.

Sandeels have a dependence on sand into which they bury at night and during the winter months[2]. During this overwintering period, sandeels emerge sometime between December and February to spawn their demersal eggs onto sand. The larvae hatch between February and April[3,4] and the planktonic larvae are transported by currents for 7-10 weeks[5,6,7].

Due to the short period that larvae drift in the water column and the fidelity of later life-stages to areas of sand, several sandeel stocks are now recognised within the North Sea[8]. The scale of larval drift and site fidelity of sandeels is reflected in the regional variation in breeding success of some seabirds[9].

Sandeel – © Marine Scotland

Scientific evidence for climate change impacts

Direct impacts on sandeels

Climate change impacts on sandeels are felt both directly through their metabolic rate and indirectly via their planktonic prey.

Sandeels feed on zooplankton in the spring and summer in order to build up energy stores to overwinter buried in sand[10]. During this overwintering period, the rate at which they use their stored energy increases with temperature and this affects their ability to allocate energy to gonad development[11,12]. This in turn means that warmer seas can delay spawning time[13]. Although embryonic duration decreases with increasing temperature[14], the effect of warm autumns and winters on gonad development predicted by many climate scenarios is expected to delay hatch times in sandeels.

POOR SYNCHRONY BETWEEN THE PEAK IN HATCH TIMES AND PREY AVAILABILITY HAS BEEN FOUND TO ADVERSELY AFFECT GROWTH AND SURVIVORSHIP LEADING TO LOW RECRUITMENT.

Whilst warming may lead to later larval hatch times for sandeels, it also tends to advance the onset of plankton blooms. The synchrony between larval hatch times and the onset of the spring plankton bloom is important to sandeels as their early larvae are limited to small prey such as copepod eggs and nauplii[15] and they need to reach a size suitable for settling by around May – June[3]. Poor synchrony between the peak in hatch times and prey availability has been found to adversely affect growth and survivorship leading to low recruitment[3,4].

These processes are summarised in Figure 1. In some cases, adverse conditions for synchrony can be reflected by a negative relationship with sea temperature[16,17,18]. However, because variation in both the timing of sandeels hatching and zooplankton prey production cycles contribute to adverse recruitment, such a simple environmental measure is not a reliable proxy of climate induced recruitment failures[19]. Warming of the North Sea has been associated with changes in the abundance of copepod species with a decline in *Calanus finmarchicus* and expansion of *Calanus helgolandicus*. However, whilst *Calanus finmarchicus* was once a key prey of adult sandeel, there is uncertainty about the importance of key prey types such as *Calanus finmarchicus* and *Calanus helgolandicus* to the diet of larval sandeels[4].

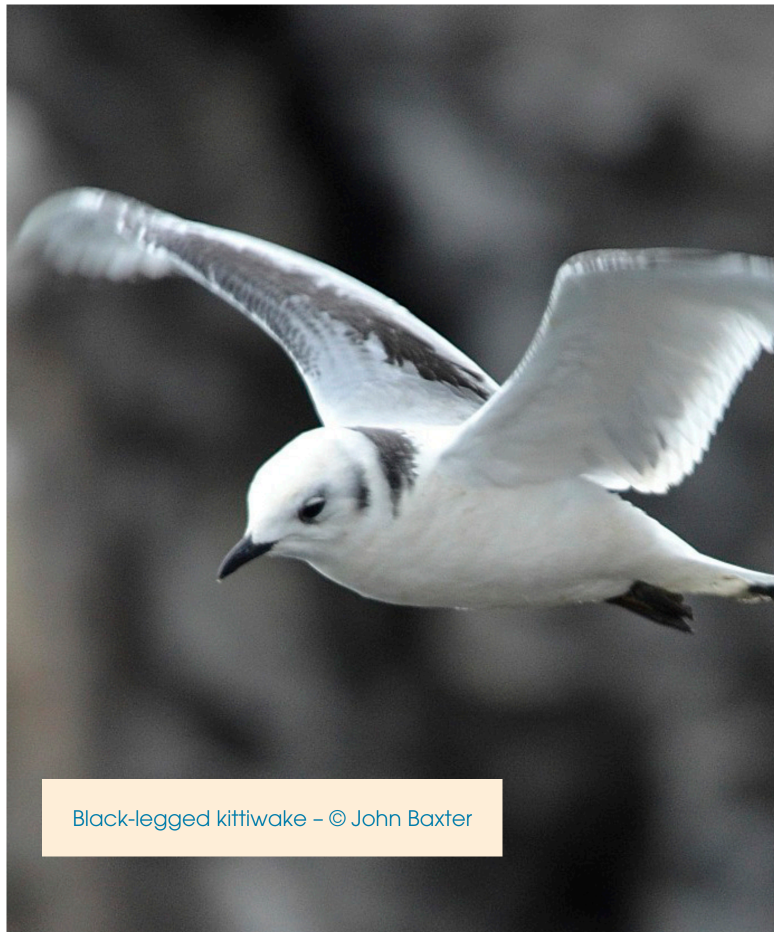
As larvae are dispersed by currents, climate induced changes in sea circulation are also likely to impact local population dynamics. For example, recruitment to Shetland sandeel grounds in the 1980s and 1990s was inversely related to the strength of inflow through the Fair Isle Channel, highlighting the importance of climate in driving changes in local population dynamics[6,7].

Implications for seabirds

Late settlement of sandeels and poor early growth can have a direct effect on seabird breeding success[20,21].

Sandeel growth rate following settlement is also important to seabirds as the adults pre-breeding condition can be affected by the size and availability of older sandeels[21]. Sandeel length and weight at age varies substantially across the North Sea[10] with those in the north-west, where most breeding seabirds forage, being particularly small. Warmer temperatures are generally associated with higher growth in settled sandeels.

Due to inter-annual differences in recruitment, sandeel stocks can undergo rapid change but the frequency of recruitment failures has generally been higher around small and more isolated aggregations such as the Shetland Isles[7] and the north-east UK[8]. However, there has been a recent increase in an alternate prey source, sprat (*Sprattus sprattus*) in the North Sea[22]. Sprats were very important in the diet of seabirds in the 1970s and early 1980s[23]. Unlike sandeels they do not store energy for reproductive development but instead feed and spawn repeatedly during spring and summer[24]. Sprat are therefore less likely to be sensitive to the timing of the onset of plankton production.



Black-legged kittiwake – © John Baxter

What is already being done to support management of sandeels in a changing climate?

Sandeel stock management

The state of sandeel stocks in the fished areas of the North Sea is currently estimated using an age-based analytical assessment model that is tuned using research vessel indices.

From these assessments ICES advises on a total allowable catch (TAC) by stock that would allow sufficient numbers to survive to spawn, which is termed an escapement strategy. As these stocks are assessed annually, it is possible to avoid fishing on a poor incoming year-class. However, the ICES advice does not explicitly consider the food requirements of predators in estimating a TAC and fisheries may locally deplete sandeel aggregations within these stock areas.

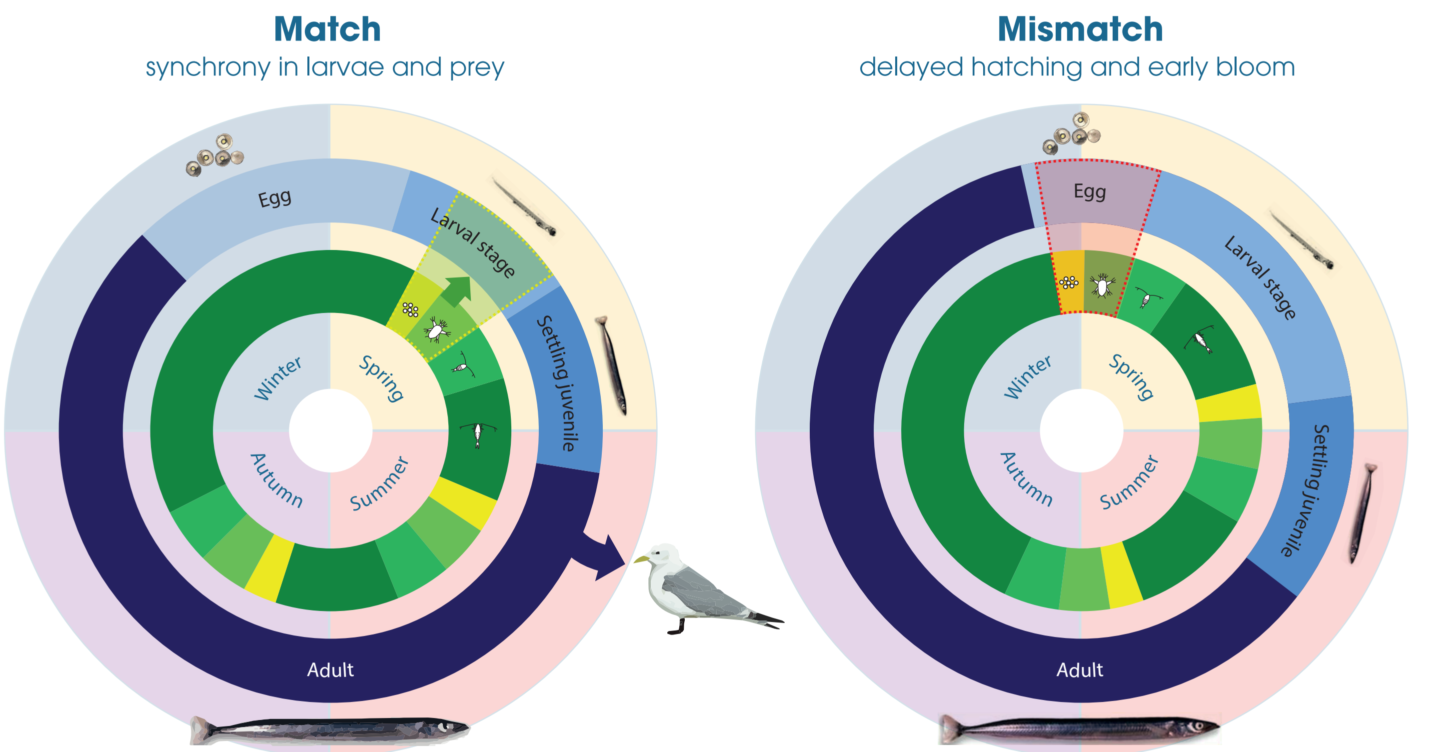
Within the SA4 stock in the north-west North Sea (Figure 2), a precautionary fishing closure was established in 2000 by the European Commission in order to protect sandeels as a prey resource for seabirds and other predators.

This north-east UK sandeel closure covers most of the foraging range of adjacent seabird colonies. Kittiwake breeding success has tended to be higher since the fishery closure than in the preceding five years, although the local stock dynamics are mainly driven by recruitment rather than changes in fishing mortality.

Sandeel designations

Under the auspices of the Marine Scotland (2010) Act three Scottish Nature Conservation Marine Protected Areas (ncMPAs) were designated with sandeels as the primary feature.

Two of these include substantial spawning aggregations which act as a source for adjacent grounds, while the third, off Shetland, has remained an important area for recruitment. However, only one of these MPAs is currently in a fished area. Scottish MPAs are reviewed every six years and the need to be adaptive to climate change is already considered in legislation.



Copepod production

- Egg
- Nauplier stages
- Copepodite stages
- Mature adult

Figure 1. Matching the onset of the spring copepod production is important for sandeel larval growth and survival. Warming can delay the timing of spawning while also advancing the onset of copepod production, resulting in a mismatch.

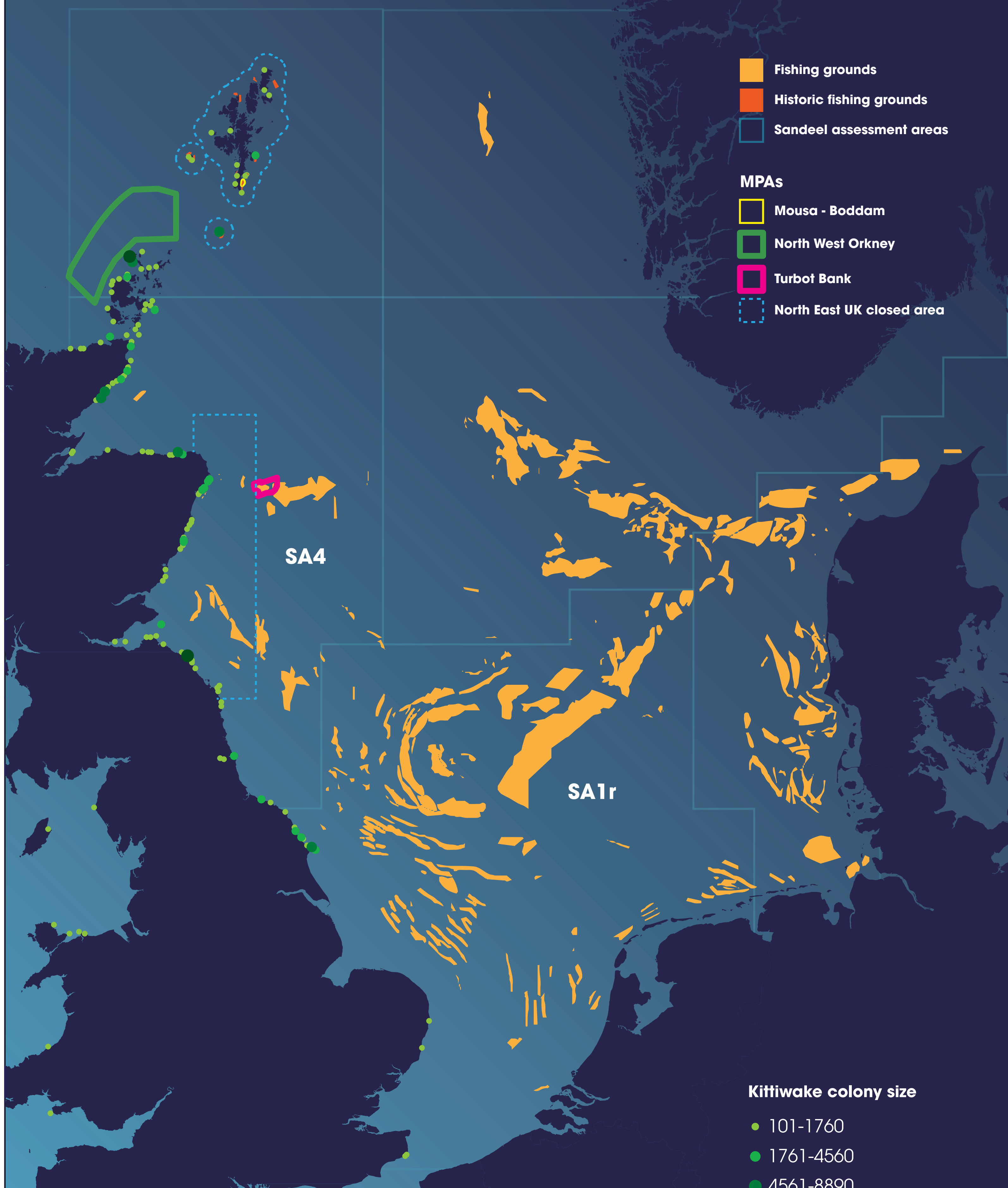


Figure 2. Chart showing sandeel fished grounds[8], MPAs (JNCC), closed areas[8] and kittiwake colonies (JNCC) (one of the seabird species reliant on sandeels).

What management measures for sandeels could also increase resilience to climate change?

As the main anthropogenic pressure on sandeels is fisheries, the main additional measures that could help maintain sufficient numbers for predators are through fisheries management, including closures.

In some areas seabirds are able to switch to alternative prey such as sprat. The decline of sprat around the north of the UK in the early 1980s was linked to a combination of a poor environment and fishing pressure. Consequently, any future expansion of sprat fisheries should consider the role of this species as a prey resource.

What wider management options could feasibly be considered?

Many of the proposed marine wind turbine developments occur on, or in the vicinity of, sandeel grounds.

Although there is presently no evidence that such developments have adversely affected local aggregations of sandeels, it is important to consider this species in renewable applications and where appropriate monitor the effects, as has happened recently for Scottish renewable developments. Protecting areas of sandeel grounds within windfarms from fishing activity may have a local benefit.

Sandeels – © Marine Scotland

Scroby Sands – © Cefas

Practical actions that could support management of sandeels in a changing climate

Most areas used by breeding seabirds are currently closed to fishing with the one major exception being grounds to the north-west of Dogger Bank (SA1) that are targeted by seabirds from the largest UK colony on the Yorkshire coast.

Monitoring and modelling activities that could help support management include:

- Consideration being given to setting aside a component of the stock biomass to avoid adverse effects on dependent predators like seabirds.
- Estimation of the sandeel biomass needed to feed the seabirds should follow the published methodology for a south-east Scottish colony[25] and use similar data from the UK Seabird Monitoring Programme.
- Monitoring of seabird diet is needed in colonies exhibiting long-term declines. The locations for diet monitoring should reflect the scale of prey population dynamics, such as the sandeel stock areas used in assessments. Where sprats are becoming a major dietary component, fishery managers should account for seabird prey requirements in the setting of fishery quotas.
- Improved habitat models together with forecasts of sea circulation could help to predict how climate change may alter the future density distribution of sandeels.
- Modelling climate-plankton-fish-seabird interactions could help consideration of when, and how, additional management measures such as closed areas would be needed (to reduce anthropogenic pressures on the prey of seabirds in the future). However, published models are currently constrained by a lack of detailed mechanistic understanding of the climate - foodweb relationships.

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Please cite this document as: MCCIP (2018). Climate change and marine conservation: Sandeels and their availability as seabird prey. (Eds. Wright P, Regnier T, Eerkes-Medrano D and Gibb F) MCCIP, Lowestoft, 8pp.
doi: 10.14465.2018.ccmco.006-sel