Offshore oil rigs – a breeding refuge for Norwegian Black-legged Kittiwakes *Rissa tridactyla*?

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Abstract

In recent decades, the population of Black-legged Kittiwake *Rissa tridactyla* has declined substantially in most parts of the North Atlantic. Concurrently, there has been an increased urbanisation of the species, with Kittiwakes colonising nearshore buildings and other man-made structures. Here we document the prevalence and performance of Kittiwakes breeding on offshore oil rigs on the Norwegian shelf and compare their reproductive output with parallel data from the nearest Kittiwake colonies monitored on the Norwegian coast. At least six (10%) of the 63 rigs addressed in the study were reported to have breeding Kittiwakes, four of which had a total of 1,164 breeding pairs in 2019. One of these offshore colonies was situated in the Barents Sea, the other five in the Norwegian Sea. Overall the Kittiwakes breeding on oil rigs had a moderate to high productivity, ranging on average between 0.61–1.07 large chicks per nest. This was higher than the productivity in most (but not all) colonies on man-made structures on the coast in the same period, and much higher than that in natural breeding habitats. The differences in Kittiwake productivity between offshore and coastal habitats are likely related to parallel differences in food availability and exposure to predators, but this warrants further study. Besides helping us explore key drivers of Kittiwake productivity, the increasing numbers of Kittiwakes breeding on man-made structures both offshore and on the coast clearly provide a significant contribution of juveniles to the impoverished Kittiwake population in Norwegian waters.

Introduction

In Norway, the recent decades have seen an increased urbanisation of the Black-legged Kittiwake *Rissa tridactyla* (hereafter 'Kittiwake'). This small pelagic surface-feeding gull, which has a Holarctic distribution and breeds in the Arctic and boreal zones throughout the Northern Hemisphere, is now found breeding on human structures along most of its Norwegian breeding range (SEAPOP unpublished data, www.seapop.no/en). The natural nesting habitat of Kittiwakes is normally narrow ledges on steep nearshore cliffs (Cramp & Simmons 1983), but the species also appears to thrive on man-made structures such as buildings and bridges (Turner 2010; Coulson 2011). There are also reports that breeding colonies have established on several offshore oil rigs on the continental shelf off Central and North Norway (Norwegian Species Observation System, www.artsobservasjoner.no). A similar phenomenon has previously been documented on offshore oil rigs in the Netherlands

(Camphuysen & Leopold 2007; Geelhoed *et al*. 2011), but its occurrence in Norwegian waters has so far drawn little attention, even if the first offshore breeding there was registered already in the early 1990s (Kåre Igesund, OKEA, pers. comm.). The establishment of Kittiwake colonies in novel breeding habitats is, however, interesting in light of the severe decline of this species in many colonies in the Atlantic Ocean (Frederiksen 2010; Descamps *et al*. 2017). The species is now listed as *Vulnerable* on the Global Red List of Threatened Species (IUCN 2019) and as *Endangered* on the Norwegian Red List (Henriksen & Hilmo 2015). In Norway, this appears to be primarily a result of reduced productivity (e.g. Reiertsen *et al*. 2013), likely enforced by increased predation from White-tailed Eagles *Haliaeetus albicilla* (Anker-Nilssen & Aarvak 2009; Hipfner *et al*. 2012) corvids and large gulls, but reduction in over-winter survival of adults is likely also at play (Reiertsen *et al*. 2014; Sandvik *et al*. 2014).

As both poor productivity and increased predation pressure can be major drivers of population decline in seabirds (Sandvik *et al*. 2012; Reiertsen *et al*. 2013; Dias *et al*. 2019), it is important to understand the environmental factors affecting productivity, such as food abundance, quality and availability. As central-place foragers during the breeding season, the foraging range of Kittiwakes is limited by the need to return to the colony at regular intervals to provision their chicks (cf. Orians & Pearson 1979). The time and energy associated with travelling between the colony and foraging areas may thus represent a major constraint in their ability to sufficiently provision themselves and their offspring. The Norwegian oil rigs are situated tens to hundreds of kilometres off the mainland coast (Figure 1). It is therefore expected that Kittiwakes breeding on oil rigs experience different food availability and exposure to predators than those breeding at coastal colonies. Given such differences in disturbance, predation pressure and distance to suitable foraging areas, the breeding biology of the 'oil rig Kittiwakes' might thus offer insight into drivers of the low productivity registered in many of the mainland colonies. In this context, it is also interesting to quantify differences in productivity between colonies associated with human settlements on the coast and those on nearby natural cliffs that are more sheltered from human traffic, as these colonies likely experience comparable food availability but different levels of disturbance from humans and predators.

In this study, we explored the prevalence of Kittiwakes breeding on offshore oil rigs on the Norwegian shelf. Using a community science approach, we examined 1) on which oil rigs Kittiwakes are breeding, 2) the size of the breeding populations on these oil rigs, and 3) their reproductive success in 2018 and 2019. We compare the results to parallel data on the performance of coastal-breeding Kittiwakes at colonies on natural cliffs and within human settlements in the same region.

Given the evident differences in human presence between the three types of habitats and the absence of corvids and birds of prey offshore, we expected the highest level of predation on Kittiwakes and their offspring on the natural cliffs followed by birds breeding on man-made structures on the coast, and that birds breeding on oil rigs experience the lowest predation pressure. As diet studies indicate that Kittiwakes in human settlements do not feed their young on food sources provided by man (SEAPOP unpublished data, www.seapop.no/en), we also expected that birds at coastal colonies would experience relatively equal food availability, whereas those breeding offshore would have different foraging areas and therefore different access to food. Consequently, if predation pressure is the main driver of productivity, we expect the offshore Kittiwake colonies to have the highest productivity, followed by those breeding on human structures. However, if food availability is the main driver of productivity, we expect the two types of coastal colonies to have similar productivity, with the offshore colonies differing from these.

The aim of our study was twofold. With almost no detailed knowledge on the breeding of seabirds on offshore oil rigs, we wanted to document the numbers, distribution and breeding performance of Kittiwakes on Norwegian oil rigs. In addition, we wanted to test if a type of community science could be applied to monitor these parameters on such locations, which under normal conditions are not accessible for researchers.

Methods

Study period and selection of colonies: The field study took place in the breeding seasons 2018 and 2019. As oil rigs are not easily accessed, successful mapping of breeding colonies offshore was dependent on co-operation with the companies operating on the Norwegian shelf. All the primary oil companies were therefore contacted through the Norwegian Oil and Gas Association (www.norskoljeoggass.no/en) and sent a questionnaire to 1) determine on which oil rigs Kittiwakes were known to breed and 2) provide rig-specific estimates of their colony sizes, with colony size measured as the number of apparently occupied nests (hereafter AONs), defined as sites attended by a pair or a single parent where nest material was observed. In addition, we asked the oil companies if they were willing to take part in a longer-term study to monitor Kittiwake breeding numbers and productivity offshore. Positive replies were received from the companies operating the rigs on the Draugen (64°21'N 7°47'E), Heidrun (65°20'N 7°19'E) and Skarv (65°41'N 7°39'E) oil fields in the Norwegian Sea, and the Goliat (71°30'N 22°30'E) oil field in the Barents Sea

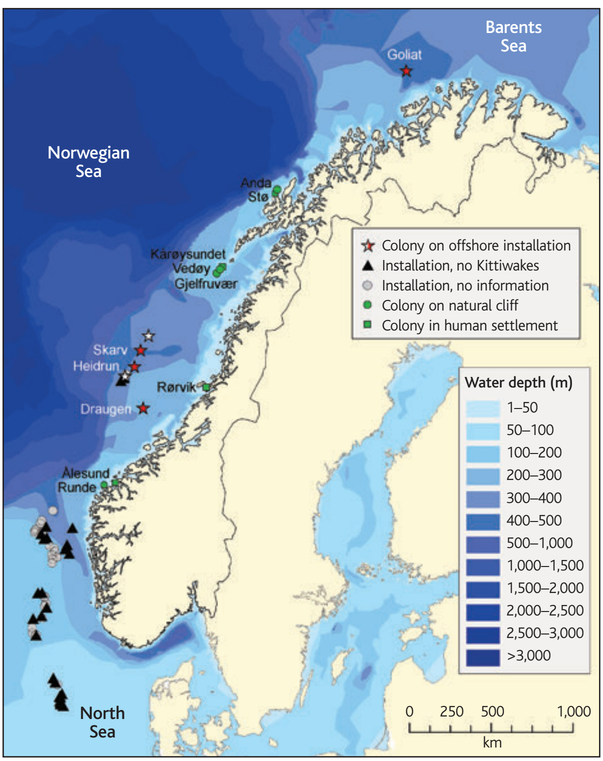

Figure 1. Map of the study colonies. Offshore oil rigs with breeding Black-legged Kittiwakes *Rissa tridactyla* are shown with a star, those in red were included in the study of productivity.

(Figure 1). These rigs are situated between 60 km and 170 km offshore and are operated by different companies (Table 1).

Besides the four offshore colonies, we used parallel data collected by the SEAPOP programme (www.seapop.no/en) in eight extant colonies on the mainland coast for comparison of productivity: Runde (62°24'N 5°37'E) in Herøy, Sildegarnsholmen (62°28'N 6°08'E) in Ålesund, Rørvik (64°52'N 11°14'E) in Vikna, Gjelfruvær (67°25'N 11°54'E), Vedøy (67°29'N 12°01'E) and Kårøysundet (67°30'N 12°05'E) in Røst, and Anda (69°03'N 15°10'E) and Stø (69°02'N 15°07'E) in Øksnes municipality. Those on Runde, Gjelfruvær, Vedøy and Anda are on natural cliffs in uninhabited areas, whereas the other four are situated inside human settlements in the same districts (Figure 1).

Table 1. Population size (no. of apparently occupied nests, AONs) and productivity (mean ± S.E.) of Black-legged Kittiwakes *Rissa tridactyla* in 2018–19 at four offshore oil rigs in Norwegian waters. FPSO = floating production and offloading unit, FCTL = floating concrete tension leg platform and CFF = concrete fixed facility. No data on breeding success were collected on Draugen in 2018 or on Goliat in either year. For Heidrun in 2018, productivity was based on a total count of large chicks in the colony and S.E. estimated by applying the distribution of nests producing zero, one and two chicks in other colonies of high breeding success (see text).

Name	Operator	Type of rig	Distance offshore (km)	Colony size 2019 (AONs)	Productivity (chicks/nest ± S.E. (n)) 2018	2019
Draugen	OKEA	CFF	75	674		1.02 ± 0.04 (241)
Heidrun	Equinor	FCTL	165	252	1.07 ± 0.03 (280)	0.62 ± 0.09 (39)
Skarv	Aker BP	FPSO	170	198	0.69 ± 0.05 (133)	0.61 ± 0.05 (198)
Goliat	Vår Energi	FPSO	60	40		

Studies of offshore colonies: The companies that agreed to participate in the study were asked to either make a total count of AONs, or take photos of the areas with breeding Kittiwakes. Such photos were subsequently counted (by SCD) to estimate the population size.

Photo documentation was also used to estimate the productivity on the oil rigs. The companies were asked to photograph sections of the colony early, mid and late in the breeding season. The number of AONs in these plots early in the season was determined from the first set of photos, whereas the number of large chicks was counted from those taken later in the season to derive an estimate of the average productivity (large chicks/nest). At that stage, nests with adults positioned such that they could have been hiding a (presumably small) chick, were considered not to fledge any chicks.

Studies in coastal colonies: Parallel data on productivity in the most relevant coastal colonies monitored by SEAPOP were analysed for comparison. Following the international standard (Walsh *et al*. 1995), AONs were usually identified in the incubation period and estimates of productivity were based on counting the number of large chicks on the same nests as close to first fledging as possible. As predation pressure may vary within each colony, we used estimates based on total colony counts when available. This was the case for all the coastal colonies, where predation is expected to be higher than offshore.

Statistical analyses: All tests were made in IBM SPSS Statistics (v. 26.0, IBM Corp. 2019). Pairwise differences were tested using independent-samples t-test, whereas one-way ANOVA was applied to test for differences among three or more groups. To allow such comparisons when not having data on the individual nest level on Heidrun in 2018 and Rørvik in both years, we applied the observed proportions of nests producing one or two chicks, respectively, in colonies with a similarly high productivity, for this purpose defined as producing more than 0.7 chicks/pair. Although this involves some pseudoreplication of data, we consider the statistical bias thereby introduced to be insignificant for the results presented here. This is because the proportion of pairs producing more than one young in those colonies only ranged between 18.6–21.5% (mean 19.5%). Thus, the variance in productivity estimates for the modified colony years, which only comprised 12% (1,024 nests) of the final data set, are likely to be very close to the true values. Only 23 (0.3%) of the remaining 7,334 nests produced three fledglings.

Results

Offshore colonies: A total of 63 offshore oil rigs operated by 11 companies were included in the study. Of these, six (10%) rigs were reported to have breeding Kittiwakes and 33 (52%) to have no breeding Kittiwakes. For the remaining 24 (38%) oil rigs we did not get any information. Thus, of the oil rigs that provided information (39 in total), there was reported breeding Kittiwakes on 15% of them. The rigs with breeding Kittiwakes were all situated in the Norwegian Sea or the Barents Sea (Figure 1).

In 2019, a total of 1,164 AONs of Kittiwakes were counted on four of the rigs, with Draugen having the largest colony with a minimum of 674 breeding pairs (Table 1). No information on population size was available for the two other rigs with breeding Kittiwakes.

The nesting habitats appeared to be highly variable, with Kittiwakes inhabiting a variety of surfaces on the oil rigs. On Skarv and Goliat, both of which are floating production storage and offloading units (FPSOs), the Kittiwakes were mainly breeding on suitable ledges on the sides of the rigs (Figure 2). On Heidrun and Draugen, the birds were primarily breeding on the main construction and the top of the shafts (Figure 3).

Compared to the tuft-like grassy nests typical of the mainland colonies, the nests on all four oil rigs were constructed quite simply with nesting material mainly consisting of dried kelp and pieces of plastic debris (Figure 3).

Productivity was recorded on Heidrun and Skarv in both study years, and also on Draugen in 2019. All productivity estimates were made from photographs except

Figure 2. Examples of breeding localities on floating production storage and offloading unit, here on Skarv © *Supply Vessels* "Viking Lady" *and* "Chieftain Island"

Figure 3. Examples of Black-legged Kittiwake *Rissa tridactyla* breeding localities on a fixed concrete rig, here on Heidrun. © *Eldar Myrene* (left) and *Signe Christensen-Dalsgaard* (right)

that for Heidrun in 2018, which was based on a total count of large chicks and newly fledged juvenile Kittiwakes on the oil rig. The estimated productivity across all three rigs and both years ranged between 0.61–1.07 large chicks per nest (Table 1). For Goliat, it was not possible to determine the number of chicks from the photos, but these still confirmed that chicks were produced on the rig in 2019. When analysing the photographs from the other rigs, it became evident that some of the chicks had already fledged at the time when the pictures were taken. The photos from Heidrun in 2019 were also from the outer areas of the rig where predation by large gulls is likely to be highest (own unpubl. observations). The productivity results reported here for the offshore colonies should therefore be considered as minimum estimates.

Onshore colonies: Productivity was registered in the coastal study colonies in both years. There was a clear tendency for lower productivity on natural cliffs than within human settlements, except for in Stø where productivity was lower than at nearby Anda (Table 2).

Table 2. Population size (no. of apparently occupied nests, AONs) and productivity (mean ± S.E.) of Black-legged Kittiwakes *Rissa tridactyla* in 2018–19 at eight coastal colonies inshore of the oil rigs included in the study of productivity (cf. Table 1). For Rørvik, productivity was based on a total count of large chicks in the colony and S.E. estimated by applying the distribution of nests producing zero, one and two chicks in other colonies of high breeding success (see text).

Name	Municipality (county code)	Type of colony area and surroundings	Colony size (AONs)		Productivity (chicks/nest ± S.E. (n))	
			2018	2019	2018	2019
Runde	Herøy (MR)	Natural habitat	450	425	0.07 ± 0.01 (450)	0.07 ± 0.01 (425)
Ålesund	Ålesund (MR)	Human settlement	615	633	0.72 ± 0.03 (615)	0.71 ± 0.03 (633)
Rørvik	Vikna (TR)	Human settlement	383	361	0.99 ± 0.03 (383)	1.21 ± 0.02 (361)
Gjelfruvær	Røst (NO)	Natural habitat	381	408	0.41 ± 0.03 (381)	0.32 ± 0.03 (408)
Vedøy	Røst (NO)	Natural habitat	319	93	0.05 ± 0.01 (319)	0.00 ± 0.00 (93)
Kårøysundet	Røst (NO)	Human settlement	752	753	0.45 ± 0.02 (752)	0.58 ± 0.03 (753)
Anda	Øksnes (NO)	Natural habitat	865	916	0.55 ± 0.03 (865)	0.45 ± 0.02 (916)
Stø	Øksnes (NO)	Human settlement	59	54	0.31 ± 0.06 (59)	0.09 ± 0.04 (54)

Comparisons across colonies: Productivity differed significantly with type of colony area ($F_{2,\ 8355} = 412.8$, $P < 0.001$) and was highest on the offshore rigs (mean 0.88 ± 0.02, n = 891), lowest on natural cliffs (mean 0.32 ± 0.01, n = 3857) and intermediate on colonies in human settlements (mean 0. 69 ± 0.01, n = 3610). The difference was apparent in both study years (2018: $F_{2,4234} = 197.2$, $P < 0.001$; 2019: $F_{2,\ 4118} = 229.0$, $P < 0.001$), even if the productivity offshore was slightly better in 2018 (0.95 ± 0.03) than in 2019 (0.82 ± 0.03, t = 3.209, df = 889, P = 0.001) whereas the opposite was the case in human settlements (0.65 ± 0.02 and 0.74 ± 0.02, respectively, t = -3.891, df = 3,608, P < 0.001). Overall, breeding success did not differ between years on natural cliffs (0.34 ± 0.01 and 0.31 ±0.01, respectively, t = -1.462, df = 3,855, P = 0.144).

Discussion

Offshore oil rigs have been in use for more than half a century, nonetheless there is still limited knowledge on their direct impact on seabirds (Ronconi *et al*. 2015). There is concern about exposure of seabirds to oil in case of oil spillage (e.g. Tasker *et al*. 1986; Haney *et al*. 2017) and mortality due to collision with the infrastructure or incineration in flares (Bourne 1979; Ronconi *et al*. 2015). However, the rigs might also act as artificial reefs creating habitat conditions attractive to marine fauna (Fowler *et al*. 2018) and provide resting and roosting sites for birds (Ronconi *et al*. 2015). Our study adds insight to another ecological function of offshore oil rigs, namely as breeding habitats for Kittiwakes. We show that there are Kittiwakes breeding on at least six oil rigs in the Norwegian parts of the Norwegian and Barents Seas, with at least 1,164 breeding pairs on four of these rigs in 2019.

Due to the inaccessibility of the offshore study sites, we had to rely on counts and photo documentation provided by the operators and supply vessel crews to estimate breeding numbers and success of their Kittiwake populations. Although these data provided usable estimates, this method of data collection led to some limitations of the study, primarily related to the timing of registrations. By not being present on the rigs, it was difficult for us to assess the best timing for photographing the colonies and the last photos were consequently taken after the first chicks had fledged. Additionally, some of the chicks were still small at this time and therefore had to be included as failed nests in the analysis. Ideally, photos should have been taken at least twice during the last part of the breeding season to successfully identify the true fate of most chicks. This being said, using a form of community science (Bonney *et al*. 2014) to map population size and breeding success on the oil rigs still proved to be a very useful tool to study Kittiwake performance in an area where it would otherwise be very difficult to get any information. Of the oil rigs asked for information on breeding Kittiwakes, 24 did not reply to the request, all of which are situated in the North Sea. This adds some uncertainty to the finding that Kittiwakes only breed on oil rigs in the Norwegian and Barents Seas and not in the rest of the Norwegian sector. The lack of response from these rigs most likely suggests no Kittiwakes are breeding on oil rigs in the Norwegian part of the North Sea, but this has to be verified before drawing final conclusions on the distribution of breeding Kittiwakes in Norwegian waters.

With a minimum productivity ranging 0.61–1.07 chicks fledged per nest, the Kittiwakes breeding on the oil rigs had a good level of chick production, ranging higher than that of Kittiwakes breeding on man-made structures on the coast except for Rørvik, and much higher than that of Kittiwakes breeding in natural habitats in our study area. These differences correspond well with the predictions of our first hypothesis and indicate that predation pressure might be a key driver of Kittiwake productivity along the part of the Norwegian coast included in our study. Our data set is however restricted both in time and space, and we lack detailed information on where the birds were foraging. Thus, we cannot exclude the possibility that food availability played a role, for instance if the birds breeding offshore also profited from a shorter distance to the best foraging areas at sea.

By breeding on the oil rigs the Kittiwakes are likely to experience a different predation pressure than birds breeding in the coastal colonies. Offshore there are no mammalian predators and very few (if any) corvids and White-tailed Eagles, all of which are known to take Kittiwake eggs and chicks, and sometimes also adults, on the mainland (e.g. Maccarone 1992; Anker-Nilssen & Aarvak 2009; Hipfner *et al*. 2012, own unpubl. observations). Oil rigs are, however, commonly used by gulls for resting and roosting (Tasker *et al*. 1986; Burke *et al*. 2012), some of which are known to prey on Kittiwake nest contents (e.g. Massaro *et al*. 2001; own unpubl. observations). The crew on Skarv and Heidrun did indeed report on periodically high numbers of Great Black-backed Gulls *Larus marinus* and Herring Gulls *L. argentatus* targeting the Kittiwakes and their offspring. Our results indicate that Kittiwakes breeding on the exposed parts of the rigs, as for instance those breeding on the side of Skarv and on the exposed sections of Heidrun, had a lower productivity than those breeding on more sheltered parts of the rigs. This might explain the apparent difference in productivity between 2018 and 2019 on Heidrun. In 2018 the whole rig was included in the survey, whereas only the outer parts were

Black-legged Kittiwakes
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checked for productivity in 2019. Consequently, it appears that the oil rigs might provide a refuge from some predators, though not eliminating predation entirely. To test this hypothesis, levels of predation need to be quantified in parallel on the offshore rigs and in different types of coastal colonies, e.g. by setting up time-lapse photography to register when (and preferably also why) chicks disappear from the nests. Such a comparative approach will make it possible to separate the effect of predation from other drivers of productivity in the different types of colonies and thus be a powerful tool for disentangling the processes leading to such marked differences in reproductive success within the same oceanic areas.

However, food availability may still have played a role in the differences that we observed. Previous studies of Kittiwakes breeding in central Norway showed that in periods with low food availability, some of the chick-feeding adults extended their foraging range up to 400 km from the colony, in order to forage at the shelf break (Christensen-Dalsgaard *et al.* 2018). At larger spatial scales, prey is often concentrated in association with specific marine features such as shelf breaks (Weimerskirch, 2007; Fauchald 2009), and the effect of shelf bottom topography on the Norwegian Coastal Current has proven to be a key determinant of important fish prey for pelagic seabirds along the Norwegian coast (Sandvik *et al.* 2016). By breeding on the oil rigs, Kittiwakes might be able to reduce the travel distance to such predictable foraging areas considerably and thereby be able to increase their foraging efficiency compared to birds breeding onshore. In our study we lacked information on the foraging distribution and diet of the Kittiwakes and were therefore not able to test this hypothesis. This warrants comparative studies of the foraging behaviour of birds breeding offshore and in the other types of colonies, preferably by parallel tracking of their foraging movements and sampling of diets.

The phenomenon of Kittiwakes breeding on offshore oil rigs is not new. In the Netherlands, it was reported as starting in 2000 (Camphuysen & de Vreeze 2005). When asked about the occurrence in Norwegian waters, the companies taking part in our study informed us that breeding on oil rigs had been registered already in the early 1990s on Draugen where oil production started in 1993, in the early 2000s on Heidrun where oil production started in 1995, and in 2014 on Skarv where oil production started in 2013. The rig at Goliat first came in place in 2016, thus the colonisation of Kittiwakes there has been very rapid.

There has so far been little focus on the pros and cons of having Kittiwakes breeding on the rigs. For the companies operating on the shelf, the main concern is of course related to human health and safety, such as the risk of bird strikes during helicopter operations, transmission of disease and that bird droppings might complicate on-board operations. In this context, larger gulls that seek to rest higher up on the rigs are considered more of a safety risk than Kittiwakes that breed on the lower parts of the rigs and normally only search for food on the ocean surface far away from the oil field. Our results strongly indicate that breeding on offshore oil rigs has more positive than negative impacts on Kittiwake productivity, and the ongoing daily human activities on the rigs did not seem to disturb the birds (own unpubl. observations). It has nonetheless been shown that disturbance of breeding Kittiwakes can negatively affect their chick production (Beale & Monaghan 2004) though the magnitude of the effect is disputable (Sandvik & Barrett 2001; Reiertsen *et al.* 2018). Such effects may be more difficult to assess at oil rigs where the disturbance is more chronic and predictable, making habituation more likely (cf. Nisbet 2000). A higher risk of oiling of birds breeding on the rigs might be a concern. During the study period, however, there were no reported observations of seriously oiled birds. Some of the birds observed by SCD on Heidrun had small smudges of oil/dirt on the head but this appeared to be from touching the rig and they did not seem to be negatively affected.

A total of 87,000 pairs of Kittiwakes were estimated to breed on the Norwegian mainland coast in 2013 (Fauchald *et al.* 2015). Representing only an additional 1.3% of this total, the Kittiwakes breeding offshore are not likely to salvage the Norwegian Kittiwake population. Nonetheless, together with the ones breeding on man-made structures on the coast they clearly help securing a significant production of juveniles to the population. In addition, studying the breeding ecology of Kittiwakes in different breeding habitats offers a unique possibility to disentangle some of the drivers of their productivity. Gulls breeding on man-made structures can be a source of conflicts for numerous reasons (Rock 2005). Still, our experience of working with oil companies to study offshore Kittiwakes colonies has so far been positive and indicates better information on the birds' performance and behaviour may act to reduce conflict levels. In this context, we emphasise the importance of keeping a good dialogue with the companies and the rig personnel on best practice for managing Kittiwakes breeding offshore, to ensure both the health of the Kittiwakes and the people operating these rigs.

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