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Assessment of impacts and potential mitigation for icebreaking vessels transiting pupping areas of an ice-breeding seal

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ABSTRACT

Icebreaker operations in the Arctic and other areas are increasing rapidly to support new industrial activities and shipping routes, but the impact on pinnipeds in these habitats is poorly explored. We present the first quantitative study of icebreakers transiting ice-breeding habitat of a phocid seal and recommendations for mitigation. Impacts were recorded from the vessel bridge during seven ice seasons 2006–2013, for Caspian seals (*Pusa caspica*) breeding on the winter ice-field of the Caspian Sea. Impacts included displacement and separation of mothers and pups, breakage of birth or nursery sites and vessel-seal collisions. The flight distance of mothers with pups ahead was < 100 m, but measurable disturbance occurred at distances exceeding 200 m. Separation distances of pups from mothers were greatest for seals < 10 m to the side of the vessel, and declined with increasing distance from the vessel. The relative risk of separation by ≥ 20 m was greatest for distances < 50 m from the vessel path. Seals on flat ice were more likely to be separated or displaced by ≥ 20 m than seals in an ice rubble field. The relative risk of vessel collisions with mothers or pups was significantly greater at night when breaking new channels (12.6 times), with vessel speeds ≥ 4 kn (7.8 times). A mitigation hierarchy is recommended for the Caspian Sea which could be applied to Arctic pinnipeds, including reducing icebreaker transits during critical periods, and using data from aerial surveys to plan routes to minimise encounters with seals. Where pre-emptive avoidance is not possible, recommendations include maintaining a safe separation from breeding seals at least 50 m beyond the distance at which measurable disturbance occurs, speed limits, use of thermal imaging at night, dedicated on-board Seal Observers, and training of vessel officers to take effective reactive measures.

1. Introduction

Shipping in Arctic waters is developing rapidly due to increased activity for oil, gas and mineral extraction. Polar tourism is also growing, and reduced sea ice cover has allowed the opening up of new transpolar cargo routes. The potential for impacts from oil and gas (O & G) exploration and increased shipping on marine mammals in Arctic ice habitat was identified in the early 1980s, with the suggestion that icebreakers could have lethal impacts on nursing pups via vessel collisions, crushing, or displaced ice (Davis, 1981; Stirling and Calvert, 1983), but since then the focus has been on oil spills, pollution, and physical injury or behavioural disturbance due to noise (Engelhardt, 1983; Weilgart, 2007). The escalation of arctic shipping is predicted to lead to increased interactions with marine mammals (Laidre et al., 2015). Collision between vessels and marine mammals is recognised as a potentially significant impact for cetaceans in open waters (Laist et al., 2001; Vanderlaan and Taggart, 2007) and in the Arctic (Reeves et al., 2014) and a programme has been established in eastern US

Abbreviations: MP, seal mother-pup pair; LP, lone pup; P, pup; M, mother; kn, knot (nautical mile); SoV, side of vessel path

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coastal waters to understand and mitigate the threat of ship strikes to right whales (Vanderlaan et al., 2009; Laist et al., 2014). Ice-breeding pinnipeds are likely to be most sensitive to vessel impacts during birthing and lactation (hereafter referred to as 'pupping'), and the first description of icebreaker impacts on seal mothers and pups was for Caspian seals (Härkönen et al., 2008). Vessel impacts have also been inferred for breeding harp seals (*Phoca groenlandica*) in the White Sea (Vorontsova et al., 2008), and a programme to avoid breeding colonies detected by an aerial survey in the White Sea was trialled in 2009 (Gershenzon et al., 2009). Huntington (2009) suggested that regulation of shipping, with clear operational guidelines to mitigate impact on marine mammals, should be developed in advance of a shipping boom rather than retrospectively, and also that conservation measures developed elsewhere may have application within the Arctic.

The Caspian seal is endemic to the land-locked Caspian Sea. Although still relatively numerous, with a population estimated at 104,000–168,000 animals in the years 2005–12 (Härkönen et al., 2008; Dmitrieva et al., 2015; Goodman and Dmitrieva, 2016), numbers have declined by 90% over the past century primarily due to over-hunting (Härkönen et al., 2012), and the species is now listed as Endangered by IUCN. A range of ongoing threats include continued hunting, fisheries-related mortality, habitat loss and ecosystem changes (Härkönen et al., 2012; Dmitrieva et al., 2013; Goodman and Dmitrieva, 2016).

Caspian seals pup and mate on the winter ice field which forms in the shallow northern Caspian Sea in January—March (Wilson et al., 2017). This area overlaps with several major oil fields, including Kashagan in the Kazakh sector, which was discovered in 2000 and entered production in October 2016 (Gizitdinov, 2016). The offshore installations are supported by vessels transporting supplies and waste (primarily sewage) along a 300 km route between artificial islands and Bautino port (Fig. A1). During the ice season the ships traverse areas of ice forming the breeding habitat of the Caspian seal (Härkönen et al., 2008; Wilson et al., 2017). In this study we quantify impacts of icebreakers transiting through the seal pupping areas and examine implications for mitigation strategies. We discuss how results of this study might be applied to seal species breeding in other frozen seas.

2. Materials and methods

2.1. Study area and vessels

Observations were made between late January and mid-March 2006–2013 from four icebreakers operated by the company Agip KCO and their contractors. The vessels use a navigation corridor extending north and north-east from Bautino approximately 300 km to the Kashagan field (Fig. A1). The corridor crosses a shallow shelf known as the 'Saddle' which has high densities of breeding seals in most years. The water depth along the shipping corridor is approximately 3–5 m, with average ice thickness up to about 50 cm. A total of 39 icebreaker transits on the Bautino-Kashagan-Bautino route were surveyed during the ice seasons 2006–2013 (Table B1). At least one icebreaker transit was observed in each year except for 2007, ranging from 1 transit in 2006 to 23 in 2012. Access to vessels was opportunistic, and determined by operational constraints.

2.2. Annual records of the vessel transit corridor overlap with seal pup distribution

Data delineating the vessel transit corridor were obtained from Agip KCO records of vessel GPS locations, and from GPS locations recorded by survey teams during observation transits. These GPS locations were used to generate a minimum convex polygon delimiting the extent of icebreaker distributions in each year using ArcGIS software (ESRI, New York). Delineation of the breeding areas in each year and areas with > 5 pups/km^2 were extracted from the results of aerial surveys carried out during the peak pupping period from mid–late February 2005–2012 (Fig. 1; Dmitrieva et al., 2015).

An estimate of overall shipping activity during the core pupping season (25th January–7th March; Wilson et al., 2017) was made using Automatic Identification System (AIS) data purchased from www.marinetraffic.com. AIS data was not available or sparse for 2006–2012, so only 2013 was taken as having representative coverage. A minimum of 102 distinct transits from 18 vessels (mean 2.4 transits per day; range 0–11) were estimated through an area around the 'Saddle', defined by the points 45.85N 49.8E, 45.85N 51.15E, 45.22N 51.15E, 45.22N 49.8E. At least 1 vessel was present in the area for 39 days of the 41 day period.

2.3. Recording of vessel-seal encounters

Observations using binoculars were made from the vessel bridge which was ~15 m above ice level for all vessels, with 1–2 observers on each side. Vessel-seal encounters and transit through ice habitat were documented using digital photograph sequences, digital voice recorders, check-sheets and notebooks. Distance of seals from the bridge was recorded using laser rangefinders (Nikon 800 and 1000) or estimated visually for seals < 30 m from the ship or during darkness. When available, hand-held GPS units were used to record vessel-seal encounter waypoints, vessel tracks, vessel speed and heading. All data were compiled in spreadsheets, together with photograph references. Altogether a total of 674 vessel-seal encounters (Encounter List) were collated for analysis. For each vessel-seal encounter the following data were recorded when available: date; time; whether it was light or dark (hours of darkness approximately 19:00–09:00 in February); type of icebreaker (A–D) in terms of vessel dimensions, deadweight and draught (Table B1; vessels A & C were run by one shipping company, B and D were run by two separate companies); GPS location; focal seal(s) type (Mothers (M), Pups (P), lone pups (LP) without mother in attendance); developmental stage of pup from 1 (new-born) to 4 (fully moulted; Wilson et al., 2017); whether the vessel was breaking a new channel or travelling in an existing channel; ice habitat type (deformed ice structures, smooth ice pans surrounded by ice ridges, or flat ice); distance or distance band from the vessel side (Distance SoV; < 10 m, 10–49 m, 50–99 m, 100–199 m); vessel speeds immediately prior to and during each vessel-seal encounter (cruising and response speeds, respectively); and a verbal description of the encounter context.

The following outcomes of encounters were recorded: collision (strike, run over or drag an animal beneath the vessel); pup wetting (lanugal pups forced into water or covered by brash ice); maximum separation distance between Mother (M) and Pup (P), and whether MP pairs were separated by ≥ 20 m; displacement of seals (any shifting of position, movement away from vessel, including M entering the water – treated as binary Yes/No outcome) and maximum displacement distance.

Displacement and MP separation distances were estimated in most cases from photographic records. For MP separations distances were estimated on the basis of adult body lengths (ABL) between Mother and Pup (1ABL = ~1 m). Displacement distances could only be estimated in a minority of cases either where physical reference points (ice features) were visible or where the observer was able to assess visually the approximate distance.

Not all data were recorded for all vessel-seal encounters owing to varying levels of training and experience of observers.

2.4. Statistical analysis

Statistical analyses and data visualisations were performed in the *R* statistical package (*R* core team 2016). Binary logistic regression, implemented in the rms *R* package (Harrell, 2016), was used to evaluate the association of predictor variables with binary encounter outcomes. Predictor variables included vessel speed; distance from side of vessel (SoV) category; seal type (MP or LP); habitat type (featured ice, or flat ice); vessel type, year, channel type (new or old), daylight status (light,