The impact of human disturbance at seal haul-outs

A literature review for the Seal Conservation Society

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Summary

The intention of this paper is to review the types of human disturbance at pinniped colonies world-wide and summarise the scientific literature assessing the impact of such disturbance. Many studies dating from the 1970s have focused on phocids, mainly harbour seals, and most have concerned recreational disturbance. Since 2000 disturbance of other phocid species have received more attention and there has also been a growing literature on recreational disturbance of otariids (fur seals and sea lions).

The types of disturbance described here include tour boats, paddle boats (kayaks and canoes), speed boats and jet-skis and recreational 'swim-with' activities, including snorkelling and scuba diving, and also aircraft over haul-pouts, icebreaking vessels and snowmobile activity. Pinniped haul-out groups considered include non-breeding animals, moulting groups and breeding groups with suckling pups.

Overt signs of seal response to disturbance grade from increased alertness and sometimes threat displays to moving towards the water and flushing into the water. Impact on pupping groups includes temporary or permanent pup separation, disruption of suckling, energetic costs and energetic deficit to pups, physiological stress and sometimes enforced move to distant or suboptimal habitat. Impact on moulting groups includes energy loss and stress, while impact on other haul-out groups causes loss of resting and digestion time and stress. Speed powercraft in the vicinity of seal haul-outs create the risk of physical trauma to animals in the water.

A distinction is made between pinniped species which are inherently 'tame' and readily allow very close human approach often to less than 20m with little overt response (most fur seals, sea lions and southern phocid seals) and those which are generally wary of human approach and flush to the water when boats may be at a distance of 200m or more (grey and harbour seals). A distinction is made between positive human-seal interaction in the water (as with juvenile grey and monk seals) and tolerance or mild avoidance of human swimmers (as with most otariids). Further distinction is made between seal species habituation to sensitive human activity, allowing for non-intrusive tour boat visits or pedestrian visits from behind a barrier, allowing for pinniped co-existence on the same coastline and conditioning, where initially positive interaction between seals and people can become a problem for either people or seals (as has occurred with monk seals in particular).

Disturbance is considered to occur if the human activity disrupts or alters the animals' normal behaviour. This includes increased alertness or movement on haul-out sites and flushing to the water, which are generally not understood by tourists to be a problem. From a strictly conservation perspective disturbance is only important if it results in decreased survival, reproductive rate or population shift or decline. Such effects have been recorded, eg for Hawaiian monk seals, California sea lions in the Gulf of California and harbour seals in Alaska – but are generally not immediately obvious and may require long term monitoring.

Introduction

Seal, sea lion and fur seal species are amphibious, spending much of their time in the water foraging, but also much time on or close to the shore (or on ice for polar species), where they rest and engage

in social interaction and mating as well as giving birth and caring for their young. The aim of the present report is to review current knowledge on present-day human disturbance of pinnipeds at and around their haul-out and breeding sites and assess its potential impact.

Seals select their shore or ice 'haul-out' sites based on their topographical suitability, which may include degree of site exposure at high tide, access to water at low tide, sheltered areas for pups of some species and safety from predators. Sites which have proved successful during most of the species' evolutionary history have often not provided a refuge from modern humans, who began killing many shore-breeding species for their oil and fur on a commercial scale from the early 19th century.

Most pinniped species are now protected from commercial killing (the harp seal in Canada and the Cape fur seal in Namibia are notable exceptions) and most species that were heavily hunted have now recovered from near extinction - the exceptions being the Japanese sea lion and the Caribbean monk seal , both of which became completely extinct by the mid 20th century (Aurioles and Trillmich 2008, McClenachan and Cooper, 2008).

Despite the reprieve from commercial exploitation, many pinniped species and populations still face threats from human activity at and around their onshore and ice haul-out and breeding sites. Pinniped-occupied coastlines and ice sheets, which were once remote, have become more accessible for human development and frequented for recreational activities. In recent years there have been a few studies of the impact of offshore industrial construction (Seuront & Prinzivalli 2005, Edren et al. 2012; Skeate et al. 2012, Thompson et al. 2013; Dähne et al. 2013) and shipping, including lethal injuries caused by vessels with ducted propellers (SMRU, 2013). However, the present report will focus on incidental disturbance at or around pinniped haul-out and breeding sites and its, usually unintended, adverse consequences. Much of the available literature concerns harbour seals in N. America and Western Europe, but there is also a growing literature from studies of fur seals and sea lions in Australasia, California and S. America. The wide range of literature on different species enables a comparative approach to understanding the effects of human disturbance on these animals.

Studies of seal haul-out disturbance

Thus far most studies of disturbance have been on harbour seals (*Phoca vitulina*)(Appendix 1, 2). This seal species inhabits temperate coastal waters world-wide and is especially well-known in Western Europe and N. America. The seals most often breed and haul out during the spring and summer months in the intertidal zone on rocky ledges, estuarine and offshore sandbanks, but they also breed on glacial ice floes in Alaska. In many areas the seals' breeding period coincides with summer holiday periods, when human recreational activities are most frequent. Many seal haul-out sites are accessible from the shore – either directly by pedestrians, or in small craft such as dinghies and kayaks. Seals may be disturbed by people intending to watch and photograph seals, or by activities such as watersports taking place in inshore habitat occupied by seals.

There have been fewer studies of grey seal (*Halichoerus grypus*) disturbance, although they also suffer similar types of human disturbance. Reasons for this may be its more restricted distribution

only along the Atlantic coasts of Western Europe and N. America, but also because it breeds more often on exposed offshore islands in the autumn and winter months. There have been a few detailed studies of other species, including the harp, Southern Elephant and Caspian seals (Appendix 3), the NZ fur seal and both Steller and Californian sea lions (Appendix 4). Some of the disturbance studied has been caused by field scientists (grey seal, S. Elephant seal, Steller sea lion) and in one species (Caspian seal) by industrial icebreakers – but, similarly to harbour seals, much of the disturbance studied has been caused by tourists and watersports.

Seal response to disturbance

Seals haul out onshore (or on ice) to rest – and in the breeding season to give birth, rear their young, and in some species also to mate. Harbour and grey seals onshore regularly raise their heads in 'alert' manner and look round, 'scanning' for predators or other danger. In an undisturbed colony of harbour seals, individual adults – including mothers with young – are usually alert for about a third of the time, and at any given moment, about one third of seals in a group will be alert (Wilson & Corpe 1996). Harbour seals hauled out alone scan more than seals hauled out in groups (Terhune 1985) but simultaneous scanning also increases with group size, and disturbance (eg by an approaching canoe) is detected at greater distances (da Silva & Terhune 1988). Individual vigilance is greatest by seals freshly hauled out and drops to a lower level after 30 min as the animals settle to rest (Terhune & Brillant 1996). In Australian and NZ fur seals, 'alert' behaviour increases with decreasing group size in the context of tour boat disturbance (Shaughnessy et al 2008).

Scanning times by individuals increase in the context of human activity, such as pedestrians onshore or nearby boat Wilson & Corpe 1996. When the % of seals canning reaches about 80%, the seals are ready to flush into the water (Fig. 1). The alert posture visibly increases to 'flight readiness' (Fig. 2). Member of a harbour seal haul-out group are closely attuned to one another, so when a single seal rushes towards the water, other group members do likewise. A study of southern elephant seal disturbance found that human presence (mainly researchers) resulted in a threefold increase in 'alert' frequency and also a decrease in maternal calling (Engelhard et al 2002). When Weddell seal mother-pup pairs were visited (experimentally) several times over a 2-hr period, 67% mothers were 'alert' at the initial approach, but only 18% by the 10th approach. By contrast, mothers and pups visited irregularly over a 3-week period did not show any habitation of 'alert' response (Van Polanen Petel et al 2008).

Harbour seal mothers may scan more frequently when their pups are newborn than when they are older (Stein 1989), but scanning times for harbour seal mothers are otherwise within the normal range for non-mothers (Wilson & Corpe 1996). Harbour seal pups lying beside their mothers scan almost not at all, but when their mothers are absent, and just after weaning at 3–4 weeks of age, their scanning increases to ~9s/min, i.e. about half the normal adult scanning time. By 2–4 months of age, pup scanning times are similar to adults (Wilson & Corpe 1996).

Grey seal mothers on the shore beside their pups were found to scan significantly less than harbour seal mothers. Grey seal pups scanned only ~3s/min when their mother was absent and this scanning

level did not increase for fully weaned pups – i.e. fully weaned grey seal pups appear to be less alert to disturbance and danger than harbour seal pups.

Types of disturbance

The types of disturbance described for harbour seal, fur seal and sea lion haul-outs include pedestrian or vehicle disturbance coming from the shore and all sorts of watercraft, namely 'paddleboats' (canoes, kayaks and dinghies), seal watching and other motor boats, cruise ships, fishing/lobster-potting boats, yachts, speedboats and jet-skis. The type of boat, distance from the seal haul-out and the angle of approach all appear to be factors in determining the level of disturbance caused. Swimmers, snorkelers and scuba divers close haul-out sites may also be sources of disturbance.

Kayaks and canoes Small paddled craft such as kayaks and canoes have been found in several studies to be a particularly strong stimulus causing seals to flush into the water. This is thought to be due to their low profile in the water, possibly resembling features of predators such as orcas or sharks (Terhune & Almon 1983, Hoover-Miller et al. 2003). Kayaks and canoes have been found to cause seals to flush into the water at greater distances (140m) than motor boats (100m) (Henry & Hamill 2001) and the presence of paddleboats has been found to be more likely (55%) to cause flushing than motor boats (11%) (Lelli & Harris 2001). At one site, 55% kayakers caused flushing to the water compared to only 9% motor boats (Suryan & Harvey 1999). At another site flushing to the water only occurred with kayaks and with motor boats that stopped at the haul-out site Johnson & Acevedo-Gutiérrez 2007). In another study kayaks and canoes caused 55% of flushes despite only constituting 40% of boat events at the same site (Fox 2008).

Fig. 1. Typical disturbance of a harbour seal haul-out caused by pedestrians approaching along the beach (Dundrum Bay, NE Ireland, April 2014).

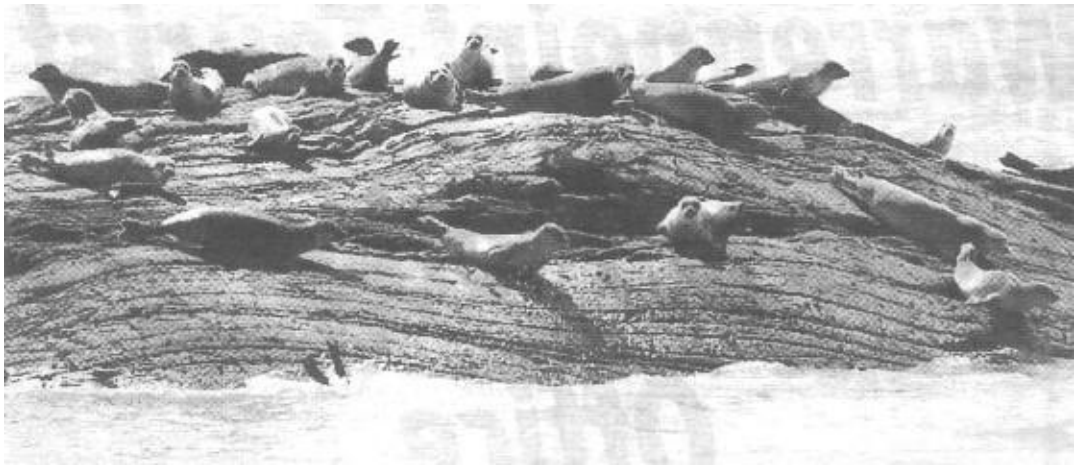

Fig. 2. Alert posture of seals immediately before all seals flushed into the water (pedestrian photographer disturbance, Dundum Bay, NE Ireland, August 2001; Photo: Mourne Observer Aug 29 2001.

Distance of disturbance from haul-out All studies of the distance of the disturbance source, from land or from the water, from the hauled-out harbour seals have found that the closer the disturbance, the more likely seals are to flush into the water. The actual distance at which most flushing to the water occurs has varied from study site to site, but has been given as approximately <100m (Allen et al 1984, Jackson & Wilson 1990, Calambokidis et al 1991, Brown & Prior 1998, Suryan & Harvey 1999, Henry & Hammill 2001, Johnson & Acevedo 2007, Fox 2008, Jansen et al 2010). By contrast, grey seal mothers responded by flushing to the water more to boat speed than to distance, although flushing generally occurred at 20–70m, with no detectable disturbance at 150m (Strong & Morris 2010). Caspian seals were also found to have a 'flight' distance of approximately 100m (Wilson et al 2008). However, the distance at which seals become alert and begin to move towards the water can be as much as 500–800m at some sites (Henry & Hammill 2001, Wilson et al. 2011) and some seals begin to move into the water at 200–300m for all vessels (Suryan & Harvey 1999), 300–500m for cruise ships (Calambokidis et al 1991), 300m for tour boats (Young 1998), 140m for kayaks (Henry & Hamill 2001), and 137m and 371m for kayaks and stopped power boats respectively (Johnson & Acevedo-Gutiérrez 2010), while 77% seals flushed when cruise ships within 200m (Jansen et al 2010) and 90% when a tour boat stopped at 30m (Young 1998). Flushing sometimes started when a seal survey zodiac approaching obliquely and paused was at average distances 190–247m for most different harbour seal sites (there was one site with an exceptional flight distance of 800m) and 129–214m for grey seals (Wilson et al. 2011). Henry & Hamill (2001) found that a higher proportion of harbour seals flushed at >200m during the pupping season. Pedestrians onshore approaching a pupping harbour seal group in Shetland caused disturbance mostly at distances <150m, with most disturbances at less than 105m, the distance depending partly on the discreetness of approach (Brown & Prior 1998), while pedestrian activity behind a pupping group in the Netherlands often caused disturbance at <200m and always at <50m (Osinga et al. 2012).

The visible response to disturbance may be less for some otariid species (fur seals and sea lions) than for harbour and grey seals. Cassini (2001) reports a 'strong response' from S. American fur seals when humans crossed the 10m threshold. New Zealand fur seals showed no behaviour change in response to tourist or researcher approach until the distance was 10–30m on shore or <10–30 from boats or kayaks (Boren et al. 2002). Australian sea lions in a nature reserve frequented by tourists commonly only 'looked' at the intruder without raising the head when the tourists came within 15m (Orsini et al 2006), although they slept ~4–6% less than normal when tourists were present on the same beach. Despite the disturbance, the sea lions did not attempt to avoid the human recreation area of the beach (Kent & Crabtree 2008). Australian fur seals 'resting' decreased to as few as 20% as tour boat approaches decreased from 100 to 20m, while for NZ fur seals the % probability of resting decreased much less – from 100% at 100m to only 60–80% at 20m (Shaughnessy et al 2008). California sea lions in Mexico did not respond to human approach until the distance was <50m, and most disturbances occurred when swimmers and kayakers were <20m (Labrada-Martagón 2005). However, Stafford-Bell et al (2010) found a weak effect of 'swim-with' tour activities within 200m of an Australian fur seal haul-out: the number of vessels present appeared to result in an increase in aggressive behaviour amongst the hauled-out seals and increasing number of swimmers in the water resulted in more seals hauling out.

Speedboats and jetskis It is generally assumed that speed and erratic movements of power vehicles in shallow water pose a collision risk to seals and small cetaceans in inshore waters, with particular risk to naive juvenile seals and porpoises (Koshinski 2008, Thurstan et al 2012). Observations of bottlenose dolphins and harbour porpoises have reported avoidance behaviour of fast craft and jet skis, with the most pronounced reaction in shallow water (reviewed by Koshinski et al 2008). There may be little overt response by hauled-out seals to passing jet-skis (Fig. 3a), but the main risk is to seals in the water around the haul-out site. One 3-month-old harbour seal pup was found stranded onshore with a fatal fracture to the ulna, caused by blunt trauma, in an inshore area close to the haul-out site frequented both by jet skis and post-weaning pups learning to forage (Fig. 3b; Wilson et al 1999).

Fig. 3. (a) Jet-ski in vicinity of harbour seal haul-out – little overt response from seals (b) 3-month old pup (tracked using VHF transmitter) stranded about 10 days after blunt trauma injury causing fracture to left ulna, Dundum Bay, NE Ireland (Wilson et al 1999).

Implications of disturbance

Immediate impact on individual seals

Separation of pup from mother.

When a mammalian mother gives birth there is an immediate post-natal bonding period during which there is an exchange of tactile, olfactory or auditory stimuli between mother and infant which establishes the initial bond between them. Pinniped mothers all give birth on shore and therefore this bonding occurs onshore. Harbour seal mothers and pups have a post-natal bonding period of up to an hour or so during which there is repeated and reciprocal nose-to-body contact (Lawson & Renouf 1985; S. Wilson unpublished data). Human disturbance during this critical period may cause flushing of mother or both mother and pup into the water. The pup may be left behind as the mother and neighbouring seals re-enter the water, or there may be confusion of mother-neonate identity in the water. Disturbance during this critical post-natal period is likely to lead to failure of mother-pup bonding and therefore permanent separation of the pup. Pup vocalisations are individually distinct and also critical to maintaining contact between mother and pup in the water and for facilitating reunion if mother and pup become separated by up to 1km (Renouf 1984, Perry & Renouf 1987; Reiman & Terhune 1993). However, ten neonates observed by Lawson and Renouf (1985) did not call for several hours after birth – and therefore the critical period during which disturbance may cause permanent 'orphaning' of harbour seal pups may last perhaps for the first tidal cycle after the birth. Instances of actual disturbance known to result directly in neonatal orphans have not been described in the literature, but have been assumed by the finding of such newborn pups of healthy birth weight alone on haul-out beaches where human disturbance is frequent (S. Wilson, unpublished data).

Harbour seal mothers may only suckle other pups if they have lost their own pup (Boness et al 1992). By contrast, Human disturbance on grey seal breeding beaches may result in interruption or disruption of mother-pup bonding and mothers nursing pups other than their own with apparent breakdown of normal mother-pup recognition (Fogden 1971).

Permanent separation of harbour seal mother and pup after the initial critical bonding period is less likely to happen except in extreme circumstances, such as storms separating mother and pup beyond the distance of vocal communication (Boness et al 1992), or injury to the mother. This is because there is usually close coordination of mother-pup movement into the water when disturbed, with the pup following the mother and the mother waiting for the pup (Jansen et al 2010). Stranding of an older pup (larger than birth weight) may still happen occasionally following a disturbance of a pupping site (Fig. 4), but unless the mother is prevented from returning to her pup by continued harassment, separation is likely to be only temporary, even if the pair do not reunite until the next tidal cycle. In five instances of temporary mother-pup separation (not known to have been due to disturbance), reunions took an average of nearly 2 hours (Groothedde 2011). Disturbance causing flushing to the sea of mothers and pups with established bonds probably rarely results in permanent separation, and therefore this should not be assumed (as in Osinga et al. 2012) without documentation of actual separations and final outcome.

Fig. 4. Jogger disturbance causing flushing to sea leaving one pup alone sleeping deeply on beach (yellow broken circle). Mother (pink broken circle) returns to beach within 2min, but cannot seem to locate sleeping pup and returns to see without reuniting, although later reunion probably occurred. Dundrum Bay, NE Ireland, July 06 2010

Suckling reduction

It has often been stated that repeated disturbance of harbour seal pupping groups may affect pup growth by reducing suckling time onshore (Reijnders 1980, Henry & Hammill 2001, Osinga et al 2012), although there is no published evidence for this. In fact, suckling time in harbour seals is unlikely to be related directly to the duration of haul-out duration because suckling tends to occur immediately after haul-out (Wilson 1974, Groothedde 2011, Wilson unpublished data) and not usually after the seals have been hauled out and resting for some time. Within a nursery site harbour seals often move from one location to another as the tide rises or falls, thus providing frequent opportunities for mother and pup to rehaul after a brief swim and initiate a new suckling bout.

A study in which the behaviour of hauled-out mother-pup pairs was recorded in the presence and absence of nearby human activity (mainly passing leisure boat traffic) found that average suckling time was markedly decreased in the presence of human activity, even though the seals did not flush to the sea (Wilson and Corpe 1996). This suggests that suckling by newly hauled-out mother-pup pairs can be disrupted by human activity in the general vicinity and frequent disturbance may therefore be deleterious to lactation and overall milk intake by the pup.

Energy deficit

Harbour seal pups. Newborn harbour seal pups typically spend an average of 40% of the time in the water (reviewed by Jansen et al 2010) and may spend more than half the tidal cycle in the water at nursery sites where haul-out sites are not exposed until half-tide (Jackson & Wilson 1990).The summer sea temperature to which nursing pups are exposed may range from 14–18° in the Swedish west coast Harding et al 2005), 9–11°C in UK waters to 3–5°C in Alaskan coastal waters (Jansen et al 2010). Modelling suggests that a typical harbour seal pup (born at ≥ 10 kg) spending 40% of its time in water between 4–12°C generates enough heat via metabolism to support normal body temperature. Further, pups of normal birth weight in 12°C water should maintain a net positive energy balance even if they spend 70% or more of their time in the water (Jansen et al. 2010). This explains why harbour seal mothers and pups in Shetland, after decades of heavy persecution, were able to spend most of their time in the relative safety of the water, even suckling regularly in the water (Venables & Venables 1955). However, newborn pups are assumed to have very high metabolic rates to compensate for their lack of blubber and small size (Miller and Irving 1975) and pups of low birth weight (<10kg) rapidly become hypothermic in water (A. Lund, 1985, unpublished data).

Energy deficiency is likely to occur due to human disturbance if pups below normal birth weight are forced into the water *or* if young pups are forced to increase the proportion of time in 3°C water (as in Alaska) to >50%, since in either case they would need to increase metabolism by consuming more milk to remain thermally neutral (Jansen et al 2010).

Moulting seals. Harbour seals (and other species) moult and grow new hair after the pupping season. During the moult both harbour and harp seals have reduced appetite and reduced resting metabolic rate (reviewed by Paterson et al 2012). High skin temperature is needed during the moult to maximise hair growth. The temperature difference between the body surface and air of hauled-out harbour seals at the peak of the moult is ~10°C and heat loss during the moult is about double that of resting metabolic rate (Paterson et al 2012). Haul-out time during the moult must therefore be maximised, since body surface heat is rapidly lost in the water. Human disturbance causing flushing to the water is therefore extremely detrimental to moulting seals, resulting in loss of energy, interruption of hair growth and prolongation of the moulting period.

Response to disturbance

The overt response of hauled-out seals to disturbance may not be a good measure of impact of the disturbance. The 'decision' made by a seal to flee may depend on a 'cost-benefit' analysis of staying put versus fleeing or escape to the water. Harbour seal mothers may not flush to the water when disturbed if they have a young pup (eg. Jackson and Wilson 1990) and moulting harbour seals may be resistant to entering the water when disturbed owing to the potential high energy loss of doing so. Breeding males of polygynous species (eg NZ fur seal) may be reluctant to abandon their territory even if disturbed (Boren et al 2002). Seals that are disturbed frequently may move to an alternative site if available, but conversely seals may not avoid disturbance if they do not have alternative suitable habitat, or if the cost of moving to an alternative site is too high (Gill et al 2001). Mothers and pups of ice-breeding seals are generally sedentary close to the birth site for the duration of the

lactation period and young nursing pups in lanugo (with the exception of ringed seals) avoid entering the ice-chilled water). If disturbed (by tourists, hunters or icebreakers) the mother harp or Caspian seal may attempt to lead the pup a short distance across the ice away from the disturbance (Kovacs & Innes 1992; Wilson et al. 2008), but even moving a short distance – and back again to the nursery site – may be energetically costly for the pup. Alternatively, mother harp, Caspian and grey seals (grey seals bred on ice until the end of the last ice age) may slip into the water, leaving the pup on the ice (or onshore, in the case of grey seals). Disturbance of grey seal pupping beaches from boats may therefore be less dangerous to the pup in terms of potential separation and energetic loss than to the harbour seal pup.

A lack of overt response to disturbance does not, therefore, indicate that disturbance has no effect Gill et al. 2001). Mothers with young may suffer stress when disturbed and therefore frequent interruption of nursing due to disturbance could affect continued lactation, hormonal balance and the quality of the mother-pup bond. Similarly, disturbance causing stress to males and females during the mating period could affect hormonal balance, pairing behaviour and coupling. Reproductive rates in Californian sea lions in the Gulf of California have declined with increasing human disturbance, possibly due to physiological stress (French et al 2011). Moulting seals remaining on the haul-out site in preference to suffering the consequences of flushing to the water may nevertheless suffer stress, which could in turn affect their health during this low point in their annual cycle.

Impact on population From a conservation perspective, human disturbance of seals is only important if it affects survival or fecundity (Gill et al. 2001). A documented example of a long-term effect of human disturbance on a breeding colony comes from the endangered Hawaiian monk seal. At an island (Green Island) in the NW Hawaiian chain a coastguard station was opened in the late 1950s and the monk seal haul-out and breeding beaches were disturbed by human and dog beach activity. The number of pups born there declined from 20–30 before the settlement to fewer than 8, and pup mortality was very high. This effect of disturbance occurred gradually over nearly 3 decades. During this period the seals were forced to move to adjacent unstable sandbanks, frequently washed by waves, where pup survival was very poor. From the late 1970s, when the seal was designated as an endangered species, regulations to regulate beach activity were introduce to reduce disturbance and since then breeding seals have successfully recolonised Green Island (Gerrodette & Gilmartin 1990).

The decline of the, now critically endangered, Mediterranean monk seal is known to have been related to expanding human populations and coastal development causing seals to be displaced from their habitat. The decline has been further exacerbated since the 1970s by 'ecotours' seeking to view monk seals in their few remaining locations (Aguilar & Lowry 2013). In 1978 UNEP and IUCN jointly called for a regulation of tourism including 'diving and visits to caves or other areas where monk seals exist or have recently existed' and prevent easy tourist access to critical monk seal habitat (Johnson & Lavigne 1999). At a second conference in 1984 it was stated that tourists compete with seals directly for former seal breeding sites. In 1986 the Council of Europe stated that 'within the core zones of monk seal sanctuaries, no tourism or boat movements should be permitted' and cited direct harassment of animals. UNEP published an Action Plan for monk seal

management in 1987. This plan stated that human access to monk seal sites should be 'completely prohibited during the breeding season and while pups are young'. Specific documentation of tourist disturbance, mostly previously unpublished, has been cited by Johnson & Lavigne (1999): in the Desertas Islands tourist were considered to pose a particularly acute threat, especially intrusion into breeding caves by scuba divers. In Croatia surviving seals 'were suffering increasing harassment by tourist boat traffic, particularly from high speed motor boats' and the monk seal is now virtually extinct in the Adriatic. In Italy summer tourist boat traffic was causing potentially lethal disturbance to seals during the pupping season; the seals are now virtually extinct in Italian waters. By the 1980s the seal was virtually extinct in Tunisia, probably largely due to 'increased disturbance by pleasure boats and skin divers'. It is now generally acknowledged that the tourism industry is a primary threat to survival and recovery of the species. In Turkey the only caves still used by seals are far removed from human activity. However, not all caves that are safe from human harassment can meet the biological needs of seal pupping (such as a beach for giving birth, nursing, a barrier against storm surges and 'nursery' pool for pups). In Sardinia 6 aborted foetuses were discovered at the mouth of a cave frequented by tourists. There have been a few reports of snorkelling divers killing monk seals with spear guns.

Role of 'tameness' in seal response to humans It is clear from species differences in flight distance from humans that some species have an inherent 'tameness', undoubtedly due to a lack of human predation during their evolutionary history. These 'tame' species, which can usually be approached within ~20m without provoking a flight or defensive response, include most fur seals and sea lions and also southern phocids which have been studied (monk seals, elephant and Weddell seals), and is undoubtedly the reason why many of these species became easy prey for human slaughter for the fur and oil trade from the early 19th century.

It has been suggested that the fear of, and avoidance towards humans now typical of Mediterranean monk seal, may be a learned rather than an inherited trait. Some juvenile seals, not having experienced personal harassment, are now showing less fear and more trust of humans. It has been suggested that some co-habitation of coastal habitat between tourists and seals may be possible in the future if tourists are prevented from causing disturbance and harassment and seals are able to habituate to human presence and to function normally in the vicinity of human activity provided critical breeding habitat is not disturbed. Such co-existence between human beach activity and habituated monk seals in parts of Hawaii has been described (Kenyon & Rice 1959; Fig. 5)[1], indicating an inherent temperamental 'tameness' of the species where it is not harassed. However, in Hawaii a distinction is drawn between habituated and conditioned seals – the latter referring to monk seals

[1] http://maui-tomorrow.org/noaa-coexisting-with-monk-seals/

Fig. 5. Hawaiian monk seal displaying (a) habituation to human presence and (b) conditioning to positive interaction with humans

(a) ***Habituation***: a large Hawaiian monk seal pup hauls out and rejoins its mother on the beach with human onlookers behind a barrier.[2]

(b) ***Conditioning***: young monk seals approach humans in the water and sometimes interact with them[3]

which become accustomed to approaching, interacting and playing with people[4], and sometimes leading to problems when the seals become older, males in particular may bite people interacting with them, which may result in individual 'problem' animals having to be removed from the wild and placed in captivity[1]. This problem does, however, seem to be unique to monk seals. Another problem for a seal 'conditioned' to interact benignly with humans is that it may be abused by some humans, as has been reported for fur seals conditioned to approaching divers and boats in Australia (Stafford-Bell et al 2010). Guidelines concerning interactions with monk seals have been summarised by NOAA as 'With support from the community, co-existence with ***habituated*** Hawaiian monk seals is almost always successful. However, even with community support, co-existence with ***conditioned*** seals is usually extremely difficult'[1]. NOAA therefore requests people to be 'good neighbours' to monk seals by sharing space with them, by not disturbing them, and by not encouraging human-seal interaction or play.

[2] https://www.youtube.com/watch?v=2rbxphShLNE (Valerie Crane)
[3] (left) http://maui-tomorrow.org/noaa-coexisting-with-monk-seals/;
(right) https://search.yahoo.com/search?p=monk+seals+play+with+humans+in+water&ei=UTF-8&fr=moz35 ('belly rub')
[4] https://search.yahoo.com/search?p=monk+seals+play+with+humans+in+water&ei=UTF-8&fr=moz35 ('belly rub')

Elephant seals also show an inherent tameness towards humans. A young juvenile in Fig. 6 is seen to approach a tourist and initiates social contact. It is not known whether this type of interaction might lead to potential problems as with monk seals, but it seems unlikely that would happen in the Antarctic environment. Studies of tourist and research station disturbance of Southern Elephant seals has found no significant effect thus far on fitness or survival, although an increase in maternal alertness has been recorded (Engelhard et al. 2002).

Fig. 6. A young Southern elephant seal approaches and enters into contact with a tourist. Gold Harbour, S. Georgia, November 2009[5]

Non-breeding NZ sea lions may appear to be unconcerned or oblivious to non-threatening or non-harassing human approach (Fig. 7). This may be due to inherent 'tameness' or habituation (human visitors are frequent), or possibly a combination of both. Such tameness, i.e. allowing or ignoring human approach even within 10m, seems to be common also to some other otariid species, including Australian sea lions and fur seals, S. American fur seals and Galapagos fur seals and sea lions (Fig. 8), but individuals older than nursing pups of these of these species have not been described as actively approaching people to seek social contact – by contrast, the behaviour of S. American and NZ fur seals in response to human approach ranges from indifference through wariness and avoidance to defensive and threatening if humans intrude on their personal space (Cassini 2001, Cassini et al. 2004; Boren et al. 2002; Orsini et al. 2006). Australian fur seals may show mild avoidance of groups of swimmers in 'swim-with' programmes (Stafford-Bell et al. 2010).

[5] https://www.youtube.com/watch?v=pW9SbaydAzM (How to cuddle with an elephant seal – CasaNostraSiciliano)

Fig. 7. A pair of young New Zealand sea lions on a beach continue their alternating resting and 'courtship' play behaviour apparently undisturbed and uninterrupted while a family with children maintain the advisory minimum 10m distance. Otago Peninsula, December 2013[6].

Fig. 8. A juvenile Galapagos sea lion sleeps, apparently undisturbed, in the midst of tourist presence[7]

Seal species which are not inherently 'tame' may habituate to human presence. Varying degrees of habituation to frequent non-harassing tour boats have been reported for harbour seals (Young 1998; Fox 2008), grey seals (Strong &Morris 2010) and for kayak approach to NZ fur seals (Boren et al 2002). Despite the frequent visits by tour boats to grey seal breeding beaches on Ramsey Island, west Wales, no reduction in reproductive rate has been recorded (Strong & Morris 2010). Habituation to human approach on shore or on ice has been reported for Weddell seal mothers (Van Polanen Petel et al 2008) but not for harp seal mothers (Kovacs and Innes 1990). Grey seals – which are not an inherently 'tame' species towards humans when hauled out –may often be attracted in the water by the presence of scuba divers and may investigate them, contact them and accept caresses underwater (Fig. 9). Although these interactions are becoming quite common at certain UK sites, there have not so far been any reports of grey seals becoming 'conditioned' through such interactions in such a way as to develop problem behaviours towards humans. There is clearly a general temperament difference between grey and harbour seals, since wild harbour seals are not know to interact with humans in the water.

[6] http://www.pinnipeds.org/seal-information/species-information-pages/sea-lions-and-fur-seals/new-zealand-sea-lion

[7] Photo donated by Les Black (the 'tourist'!)

Fig. 9. Juvenile grey seal interacting with diver at Farne Islands[8]

Conclusions

Human interaction with individuals or colonies of seals, sea lions and fur seals can be considered to cause disturbance if the interaction disrupts or alters the animals' normal behaviour. With the exception of the deliberate harassment of monk seals on Kure Atoll between 1950s to the 1970s, most of the present-day disturbance reviewed here does not involve the intent to cause harm. Nevertheless, approach by humans wanting to experience seals up close, swim with or photograph them can cause varying degrees of disturbance, depending on the species, its typical behaviour, level of inherent 'tameness' and conservation status. Benign human interaction with seal colonies, causing no significant disruption to the animal's normal behaviour, occurs when pedestrians or boats approach a non-breeding colony without crossing the boundary of the seals' flight distance or territorial or personal space or without causing a detectable change in behaviour.

Positive mutual interaction Positive interaction between seals and people can sometimes occur if the seals are allowed to take the initiative, as in the cases cited above with grey seals in the water (Fig. 9) or juvenile elephant seals on land (Fig. 6). These interactions are not significantly disrupting the seals' normal activities. Young grey seals often spend much time playing with each other in the shallow waters surrounding their haul-out site and they are merely re-directing a small fraction of their attentions towards the human diver. Feeding usually occurs during foraging trips at considerable distance from the haul-out site, so these interactions are not distracting seals from feeding. Juvenile elephant seals on land may play together and rest in close association with one another; the juvenile in Fig. 6 was not losing any significant resting time and was evidently not stressed by the tourist encounter! Disturbance does not appear to be occurring either at the individual or population level.

Although such positive interactions can be initiated by juvenile monk seals, people are asked not to encourage such encounters or actively play with young monk seals because of the potential adverse consequences to the individual seals, and also to the survival of these critically endangered species.

Benign non-interactive approach People, either pedestrians or boats, approach quietly and sensitively, remain either well-hidden or outside the seals' flight distance, and do not cause an

[8] https://www.youtube.com/watch?v=sYvNLGo3Q3g ('nose rub' – Ben Burville)

increase in seal alertness, threatening or avoidance behaviour. Such situations are not technically 'interactions', since the seals should be either oblivious or indifferent to the human presence. This situation can occur with non-breeding individuals or groups of inherently 'tame' species, such as New Zealand or Galapagos sea lions and fur seals. These situations may lead to habituation and sustainable co-existence between humans and pinnipeds.

'Swim-with' activities, where humans swim 'in parallel' with the seals, can also be benign, as with the Australian fur seal and Galapagos sea lion, *provided* the dive boat is at an appropriate distance from the haul-out site, where the number of swimmers at any one time is low, people behave quietly, and where seals can establish their own distance from swimmers. Scientists have determined minimum approach distances for boats to fur seals and sea lions, and generally recommend that recommended distances should be increased from 10–20m to 20–40m, according to species and situation.

Safe boat approach or swimming distance for tourists should be based on scientists' recommendations for each species and population. As an overall generalisation, *unless habituation has been established by frequent non-intrusive visits*, safe boat distance for harbour and grey seals is about 170–200m and for most fur seal and sea lion species about 30–50m.

Non-benign approach constituting disturbance Swimming and diving around breeding colonies may not be benign. Apparently insensitive and noisy people in motor launches, swimming and snorkelling around breeding colonies of California sea lions in the Gulf of California result in sea lions flushing to the water and in the longer-term have resulted in a decreased reproductive rate of disturbed colonies.

Speedboats and personal water craft (jet skis etc) are never acceptable in the vicinity of seal haul-out sites: hauled-out seals may not respond to them overtly, but seals in the water nearby – especially young juveniles foraging or sleeping – are highly likely to be fatally injured by propeller wounds or blunt trauma.

Kayaking within 150m (and sometimes at greater distance) of harbour and grey seal colonies is not benign, since it causes seals to flush to the water. Kayakers often assume this is harmless, because flushed seals often swim towards the kayakers, displaying curiosity. As discussed above, the potential consequences of kayak disturbance to harbour seals in the summer breeding season is not only that any seals' rest and digestion are disrupted, but also that newborn pups may be separated from their mothers, low-birth-weight pups may suffer thermal stress and energy deficit, suckling may be interrupted with consequent stress caused to lactating females, and later in the summer moulting seals may suffer serious energetic costs when flushed into the water.

Visible approach to harbour or grey seal haul-outs, by pedestrians or boats, within their flight distance is never benign, even in non-breeding seasons. The permitted approach distance (usually 150–200m unless the colony is habituated) for any colony subject to human disturbance should be stated in notices at the colony approach routes. Disturbance could be operationally defined as one or more seals flushing into the water. People could be warned that approach resulting in more than 30% seals 'alert' indicates readiness to flush into the water.

Pedestrian intrusion on breeding colonies of any seal, sea lion or fur seal species (i.e. colonies with newborn pups and males in breeding condition) should be prohibited. People should watch only from a concealed or safe vantage point *or* from a boat outside the seals' 'alert' distance.

From a more positive perspective, it should be possible for increasing number of tourists to enjoy pinnipeds in the wild without the experience being to the animals' detriment. As biologists learn more about their behaviour, critical habitat requirements and response to humans and sensitivities, it will be possible for both tour companies and local authorities to design ways of fostering habituation, non-intrusive human approach and viewing methods so that humans and pinnipeds may co-exist in relative harmony into the future.

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Appendices. Summary of studies reviewed

Studies cites in chronological order within each appendix. Data relating to distances highlighted in red type

Appendix 1. Impact of disturbance on harbour and grey seals

Species	Location/date	Disturbance source	Impact on seals	Authors
Grey seals	Orkney	Field scientists on breeding beach	Inconsistent suckling of a mother's own pup and other pups, apparently caused by break-down in mother-pup bonding	Fogden 1971
Harbour seals	Indian Point, Blue Hill Bay, Mt Desert island, Maine, April–July 1976	Boats (mainly kayaks/canoes, fishing boats & yachts; details not given), mostly after Memorial day weekend (end of May) and subsequent weekends	Disturbance was infrequent during main birthing period in mid-May. Disturbance to seals considered to be most detrimental when it disrupting initial haul-out behaviour on the freshly ebbing tide. Socialisation, especially among juveniles, was observed to occur during this initial haul-out period. If a disturbance occurred while seals were assembling at a newly emerging ledge, that ledge would be abandoned and the haul-out would begin again at a less exposed ledge. If all ledges were already exposed at the time of the disturbance, the seals would leave the area. An especially vulnerable time was thought to be mid-late June, when weaned pups were assembling into pup groups around the haul-out ledges and integrating with older juveniles.	Wilson 1978
Harbour and grey seals	Miquelon, Newfoundland, June 1980	Vehicles on beach, boats close to seals, tourists wading out to sand flats to photograph pups. 41 disturbances over 2-week obs. period	After disturbance slight increase in seals moving out of bay through channel to sea. Seabound mothers and pups only recorded after disturbance. Grey seals showed possibly higher seabound movement after disturbance than harbour seals.	Renouf et al. 1981

			Harbour seal breeding site fidelity despite disturbance noted	
Harbour seal	Bay of Fundy, new Brunswick, Canada, Nov 1981–April 1983, most between June–August	Between late June to late October 22 instances of human-related disturbances recorded, including aircraft, motor boats, canoes, people and dogs on beach.	Nearby aircraft usually flushed seals to water. Canoe or small motor boat in view usually flushed seals, with exception of fishing boats picking lobster pots or laying nets. When nets set between haul-out rocks and shore, seals used offshore side of rocks.	Terhune & Almon 1983
Harbour seal	Bolinas Lagoon, Calif., year-round 1978–79	Seals disturbed on 71% days monitored throughout year. 33% non-power boats (mainly canoes); 10% pedestrians, 8% power boats, 3% clam/bait diggers, 3% dogs; most disturbance at <100m	Distance from disturbance source more important than type. Seals sometimes rehauled, depending on tide etc. On 8/13 days of bait harvesters seals did not return. 1 of 3 dead pups in 1979 was killed by a dog.	Allen et al. 1984
Harbour seal	Rhine delta area, Netherlands 1955–1980	Possibly mainly from recreational yachting	Seals in delta area declined from ~1000 seals in 1950 to extinction in 1980. Explosive increase in yachting from 1955–1980. Decline of seals up to 1960 probably due to hunting; POPs probably also played a role from 1960s, but population thought to have been also affected by increase in recreational boating from 1960s.	Reijnders 1985
Harbour and grey seals	Seal Sands, Tees estuary, NE England, Feb–Dec 1989	Response to potential disturbances by 14 land approaches, 57 boat approaches and 5 helicopters. Boats included dredgers (15), work boats/tugs (7), launch (11), zodiac (14), sampling boat (4), tourist boat (10), fishing boats (1) and speedboats (3). Dredgers and workboats entering a dry dock downstream from the main haul-out site did not usually come closer to the seals than ~150m, and did not usually cause seals to return to the water. If vessels proceeded further up the channel, they inevitably passed <100m from the seals, and in such cases at least 1–2 seals flushed to the water.	Seals at Seal Sands have the opportunity to haul out for ~3 hours each side of low water while the mudflats are exposed. For two hours each side of low water they haul-out on the opposite side of an industrial channel opposite several sites of heavy industry activity. The width of the channel separating the seal haul-out from these industrial sites is ~200m. All seals in the group (except a mother-pup pair) flushed to water on 17 occasions, including 3 dredgers and workboats, 4 zodiacs, 4 tourist boats, 3 pedestrians and 1 car, 1 loud noise and 1 helicopter. All 4 tourist boats, 3 zodiacs, 1 pedestrian and the car made direct approaches, which always resulted in seals flushing to the	Jackson & Wilson 1990

			water. Four other disturbances caused >50% seals to flush and 5 disturbances affected seals' movement from one site to another on the ebbing tide. There were 8 potential disturbances recorded during 5 days when a mother was present with her neonatal pup. The mother twice failed to flush to the water with all other seals and once the mother approached the cause of the disturbance (a zodiac).	
Harbour seal (mothers)	NE Ireland, Jun–Aug 1994–95	Various sources, including (most often) motorised yachts passing by, people and/or dogs on nearby shoreline	Average nursing time per 1-min observation in undisturbed contexts was 6 s/min in 1994 (n=283) and 5–6 s/min in 1995 (n=265). Average nursing time in disturbed contexts was 1 s/min in 1994 (n=46) and 0 s/min in 1995 (n=21).	Wilson & Corpe 1996, Ch. 2
Harbour seal, pupping colony including 25 pups	Mousa, Shetland, summer 1997	Pedestrian visitors to island, observations of 1,104 visitors, av. 29 per day. 75% visitors approached haul-out seals to within 100m and 37% to within 50m. Visitors with cameras/camcorders approached closer av. 31.9m) than those without (av. 55.8m). Some people crept stealthily or photographed from behind dykes, but most approached seals directly, being silhouetted against skyline. RECOMMENDATION: signs should be erected and buffer zone marked using natural features around pool areas used by mothers and pups to discourage people from approaching these areas.	No difference in scanning frequency in visitor presence and absence. 56% of 288 'alerts' (head orientation to source of disturbance) result of visitors. Average 'alert' frequency was 0.9/hr with no visitors present and 1.7/hr when visitors present. 93% of 208 flushings to water result of visitor disturbance 1% due to boats, 2% due to sheep, 4% unID), av. 0.1/hr in absence of people, 0.9/hr in human presence. Disturbance of nursing mothers and one female in labour observed. ~10% instances seals flushed with disturbance source >105m. 65% flushings occurred when visitors approached to <60m. During disturbed periods seal numbers declined after mid-afternoon, but when undisturbed numbers continued increasing until evening.	Brown & Prior 1998
Harbour and grey seals	Scillies, Dunvegan Loch, Wash, April–May 1997	Tour boats	Response of seals varied. Scillies (grey seals): boat at 10m, 4/17 seals >water, 30% remaining vigilant. Dunvegan L (harbour seals): boat at 4m, <5% seals >w, <30% vigilant; Wash (harbour seals): 1/3 seals	Young 1998

			> w when boat 300m, boat at 30m, most seals >w and left area, 10% remained, 30% vigilant. Habituation at Dunvegan (25 yr business) and some habituation at Scillies.	
Harbour seal	Northern San Juan Islands, Washington State, Jul–Aug 1991 & Jun–Sept 1992	Most (74% of 96 occurrences) were power boats approaching to view seals, kayaks/canoes were relatively uncommon (causing 11% disturbances), but 55% kayakers (n=11) harassed seals, whereas only 9% power boats (n=436) caused harassment. Powerboat speed not a significant factor. 25% harassments when vessels <100m from seals, 50% at 100–200m and 25% at 200–300m.	Disturbance on >71% survey days. Overall, only 39% all harassments resulted in full recovery, suggesting many seals remained in the water or moved to a different site. Less recovery of seals at p[upping site and alternative sites for mother-pup pairs limited in San Juan area. Greater adult vigilance at pupping site. Seals remaining onshore or returning following initial disturbance were less readily disturbed	Suryan & Harvey 1999; Stein, 1989
Harbour seal	NE Ireland, Aug–Oct 1996	High-speed water craft, probably jet-ski, suspected	Fatal injury caused to 3-month-old VHF-tracked pup. Pup behaviour normal and appearance healthy on Oct 10. On Oct 15-20 appeared weak, stranded on Oct 24 with fracture of distal region of left ulna and pus-filled left flipper. Fracture caused by blunt trauma, probably from jet-skis frequenting nearby coastal area.	Wilson et al. 1999
Harbour seal	Tugidak Island, Alaska, pupping season in 1970s, especially 1976 and 1978	Recreational and mining activities (especially 1978) and low-flying aircraft (especially 1976)	Disturbances from recreational and mining activites during 1970s 'resulted in frequent separations of mothers and pups'; disturbance from low-flying aircraft caused 'stampeding' of pupping colonies and may have led to separation and death of more than 200 (10%) of pups in 1976.	Jemison & Kelly 2001, Johnson 1977
Harbour seal	Southern Gulf of Maine, August 1997–2000	Seals flushed off ledges on 85 occasions in 122 days observation. 93% caused by boats. 55% paddled boats (eg canoes) caused flushing, while 11% motor boats did so. Distance not given	Boat disturbance has 'a large impact on harbour seal haul-out behaviour'	Lelli & Harris 2001
Harbour seal	St Lawrence estuary, Québec, May–August 1997	Disturbance most often caused by kayaks and canoes (33%), motor boats (28%) and yachts (18%). Kayaks/canoes elicited flushing response of 86%, motor boats 74%. Seals flushed into water when boats	Numbers of seals hauled out decreased after disturbance except during moult. 11–34% time spent in 'alert' behaviour, which increased during a disturbance. Also disturbance affected daily haul-	Henry & Hammill 2001

		were >200m and % seals flushing increased when boats approached to <100m. A higher proportion of seals flushed at >200m during pupping season. Kayaks/canoes caused flushing at mean 140m distance, motor boats at 100m.	out pattern	
Harbour seal	Aialik Bay, southcentral Alaska (ice floes), 2002–03	All types of vessel from kayaks to eco-tour ships	Disturbance monitored via remote controlled cameras sites at 3 haul-out sites. Disturbances expressed as minor (<6 seals flushed to water) and major (>6 seals). Major disturbances from tour ships decreased between 1996–2003, due to video monitoring and development of guidelines. However, kayakers appear not to act according to guidelines, although seals 'particularly sensitive to the movements and low profiles of kayakers'.	Hoover-Miller et al. 2003
Harbour seal	Muir Inlet, Woodward Bay, Alaska (ice floes)	Cruise ships	Increasing proportion of seals entered water when cruise ships <500m, 50% entering water when ships <300m and >90% when ships <100m.	Calambokidis et al. 1991 (unpublished report cited by Jansen et al, 2010)
Harbour seal	Puget Sound, Washington State, June–Sept 2004	Observed 7 kayak groups, 7 stopped powerboats and 173 moving power boats when ≤600m from haul-out sites. The 91m buffer zone was violated by 6/7 kayak groups, 4/7 stopped power boats and 8/173 moving power boats. Disturbances only caused by kayaks and stopped power boats. Seals flushed when kayaks were 37–137m distant and when stopped powerboats were 27–371m distant. All seals >w, including pups during disturbances. Seals hauled out again relatively quickly. Alternative nearby sites are limited.	NOAA guidelines prohibit intentional approach by humans and vessels within a 'buffer zone' distance of 91m (100 y ds) from any marine mammal, in water or on land. The study aim was to assess compliance by different vessel types. Disturbance defined as any activity resulting in flushing seals into water. The authors suggest that education combined with enforcement is necessary to reduce harassment. The buffer zone could be made flexible according to vessel type – i.e. moving powerboats not approaching seals could approach within ~30m with no disturbance, whereas stopped powerboats and kayaks beyond the buffer zone resulted in disturbances.	Johnson & Acevedo-Gutiérrez 2007
Harbour seal	Bair Island refuge, SF	Motor boats represented 49% 112 boat events	Defined seals as 'relaxed', 'alert', 'disturbed' or	Fox 2008

	Bay, California, March 2006–June 2007	recorded, kayaks/canoes 40% and rowboats 11%. Also researchers walking to observation point.	'flushed'. Significant drop in %seals 'relaxed' as boat or boats pass by, with recovery to pre-event levels within 10 min. % seals 'relaxed' was lowest when boats were <50m, intermediate for boats 50–100m and least at >100m. Seals flushed into water on 28% of 112 boat events. Kayaks/canoes rcaused 55% flushes, motor boats 35% and rowboats 10%. Seal vigilance increased as boats passed closer to shore. Boat speed, noise and orientation did not affect likelihood of flushing. Flushing occurred (0.17 flushes/hr) half as often as at two other sites in SF Bay. Seals at this site demonstrated a degree of habituation to non-threatening boats in this study.	
Harbour seal	Disenchantment Bay, Alaska (ice floes), May–Aug 2002	Cruise ships	Distance and bearing of ship from seals related to risk of seals entering water: seals 25x more likely to enter water when ship <100m than when ship at 500m. Most (77%) seals approached within 200m flushed into water. Risk was 3.7x greater when ship approached seals directly than when seals to side of ship. Pups may incur energy deficit in ice-chilled water for >50% time. Pup productivity at Disenchantment Bay <50% that of other ice haul-out areas in Alaska, possibly due to disturbance effect.	Jansen et al. 2010
Grey seal	Ramsey Island, Pembrokeshire (mothers and pups), Aug–Nov 2005	Tour boats.	Up to ~80 potentially disturbing visits/day by tour boats. 24% ecotour boats caused mothers to stop suckling, orientate or move towards the sea or flush to the water. No relationship between number of boats and level of disturbance, increased disturbance level at increased boat speed and increased disturbance at decreasing distance to shore, (seals flushing to water at	Strong & Morris 2010

			distances ~20–70m) with no detectable disturbance at 150m. Largest contributor to disturbance was increased boat speed. No boats observed to approach within the 20m limit in the marine code. 13% non-compliance with speed restrictions in code and another 20% marginal non-compliance, especially when departing. Recommendation that minimum distance be extended to 50m	
Harbour and grey seals	Carlingford Lough, NE Ireland, July–Sep 2008–2011	Survey vessel (motorized dinghy or RIB) counting and photographing seals for photo-count. Distances from boat to seal haul-out measured with laser range-finder.	Harbour and grey seals were counted from a survey boat during the summer harbour seal pupping and moulting seasons at 8 different sites within the Lough. The boat attempted to approach obliquely in order to get close enough to photograph the seals for a photo count without causing flushing to the water. No flushing of harbour seals was recorded at average distances of 205–362m (n= 34 approaches at 8 sites) and 170–238m (n=14 approaches at 3 sites) for grey seals. However, at least one harbour seal flushed to the water at average distances ranging from 190–802m for harbour seals (n=11 at 4 sites) and for grey seals at 129–214m (n=11 at 3 sites).	Wilson et al. 2011
Harbour seal	Dollard estuary, Dutch Wadden Sea, June–July 2007–2010	Human activities on land, including walking on dyke behind sand ridges occupied by seals (<200m), also vehicles on top of dyke. Boats also formerly caused disturbance, although the sand ridges and sandbanks now have protected area status and boats are relatively rare.	344 disturbances in 692h observation resulted in seals being 'alerted' (0.36/h) sometimes leading to flushing into water of some seals (0.14 flushings/h). 8% land activities resulted in flushing into water. Disturbances from propeller aircraft, jet-fighters and helicopters also occurred, the mean number of seals disturbed by jet-fighters was much higher than for all other types of disturbance.	Groothedde 2011, Osinga et al. 2012
Harbour seal	Beauly Firth (Moray Firth, E. Scotland), July	two jet skis photographed	Area where jet skis photographed in area where harbour seal numbers have declined considerably	SMRU 2013 -03 (p. 112, s.2.1.1)

	14 2012		since 2010	

Appendix 2. 'Alert', 'scanning' behaviour of seals

Species	Location/date	Disturbance source	Impact on seals	Authors
Harbour seal	Bay of Fundy, New Brunswick, Canada, June–August 1983	Being shot at, humans and dogs walking on beach, boat or light aircraft approach. Time spent scanning recorded for individuals hauled out alone and in groups of different sizes. Similar response (flushing into water) to all types of disturbance	Seal vigilance (scanning) time related to group size. Seals scanned most (85% time) when hauled out singly and least (27%) in largest groups of 41–54 seals). Scanning precludes deep sleep.	Terhune 1985
Harbour seal	Miquelon, Newfoundland, May–July 1984	Most disturbances causing flushing from beach, vehicles on beach, people approaching seals from behind group by wading across shallow channel or boats driving directly into herd	Scanning by adults and juveniles in all group sizes greater during post-pupping (presumably mating) period June 19–July 15 than during pupping. Adult males scanned more frequently in larger groups. Scanning seals watched water more often than beach. Authors suggest that increased scanning by males in mating season may relate partly to searching for mates rather than to disturbance levels	Renouf & Lawson 1986
Harbour seal	Bay of Fundy, New Brunswick, Canada, May–August 1984	Experimental disturbance by approaching in canoe and monitoring seals' response	Seals spent less time scanning as group size increased, but simultaneous scanning increased with group size. Approaches by canoe were detected (measured by prolonged staring at canoe) at greater distances as group size increased.	Da Silva & Terhune 1988
Harbour seal	Grays Harbor, Washington State	Recorded scanning by mothers	mothers with pups scanned more frequently when pups 1–9 days old than when pups were older.	Stein 1989 (cited by Suryan & Harvey, 1999)
Harbour seal	Bay of Fundy, New Brunswick, Canada, June–October 1992	Recorded scanning times, mostly in post-breeding period	Most data collected in post-breeding period. Results confirmed earlier studies that scanning times decrease with increasing herd size (although this scanning not incompatible with searching for mates). Individual vigilance highest immediately after haul-out and dropped to lower level within 30 min. When a single seal rushed to water, all group members did likewise.	Terhune & Brillant 1996
Harbour seals (and small numbers of	NE Ireland, Feb–Jun 1994	Recorded individual scanning times and % group scanning in pre-breeding period	When no human activity nearby, individual scanning ≤ 20s/min and % group scanning <30%. In context of human activity individual scanning ranged from 15–53 s/min and % group 18–	Wilson & Corpe 1996, Ch.1

grey seals)			80%. Seals did not usually return to water until nearly 80% group were scanning.	
Harbour seal (mothers)	NE Ireland Jun-Aug 1994–95	Pupping season	In undisturbed contexts, mother scanning times ranged from average11 s/min by mothers in large groups (>11 seals, n=66) to 19 s/min in small groups (4–8 seals, n=144). A significant correlation was found between mother scanning times and group size (range 4–7 seals, excl. pups). When human activity nearby (speedboat, motorised dinghy, children and dogs at water's edge), mother-scanning rose to 37–53 s/min, and % mothers scanning rose to 57–77% when motorised yachts passed in the channel (n=12).	Wilson & Corpe 1996, Ch 2
Grey seal (mothers)	NE Ireland, Sep–Nov 1994	Recorded scanning times by grey seal mothers in undisturbed contexts and compared with harbour seal mothers	Average scanning time for grey seal mothers at two sites in undisturbed contexts were 12 s/min (n=36) and 6 s/min (n=135). These scanning times were significantly less than for harbour seal mothers (17 s/min, n=85 and 15 s/min, n=40 at similar undisturbed sites.	Wilson & Corpe 1996, Ch.3
Harbour and grey seals (pups)	NE Ireland, Jun-Aug 1994–95	Recorded scanning times by harbour and grey seal pups, in their mother's presence and absence	Harbour seal pup scanning increased from an average of 1s/min by pups beside their mothers to 9s/min by pups without their mothers and immediately after weaning, to up to 25s/min from 2–4 months of age. During the immediate pre-weaning period mean scanning times for pups were slightly higher (3.5 s/min) than when she was present (1.1 s/min). Unweaned grey seal pups beside their mother scanned for 1.7 s/min and for 3.2 s/min in her absence. Fully weaned pups scanned on average 1.8 s/min.	Wilson & Corpe 1996, Ch.4
Harbour seals (moulting group) and grey seals	Ballykinler, NE Ireland, Aug–Sept 1994–95	Recorded % group scanning, during disturbance, flushing to water and % re-hauling within 30 min. Maximum seal counts in group were 95 including 11 grey seals (1994) and 110 including 18 greys (1995)	Scanning levels when seals undisturbed were relatively high at this site, at 12–39%. Joggers or people with dogs heading towards seals caused scanning by 57–100% of the group. All seals in the group flushed into the water when people or dogs headed straight towards them and an average of 52% (n=4) had not rehauled within 30 min. After the problem was explained to joggers, they kept to the top of the beach and fewer seals entered the water (average 20% of group, n=3), although most (78%) of those that were flushed did not rehaul	Wilson & Corpe 1996, Ch.5

			within 30min. Seals that did rehaul after a disturbance usually went to a different area of the beach.	
Weddell seals (mothers and pups)	Vicinity of Antarctic research stations	Tested the effect (proportion of seals 'alert') of regular visitation of mother-pup pairs over 2 hr period and compared with irregular visitation over 3-week period.	Seals responded to human approach by looking up ('alert'). 67% mothers 'alert' on initial approach, habituation to 18% at 10th approach during 2h period. However, neither mothers nor pups habituated to irregular human activity over 3-week period: the majority of mothers in disturbed colonies were alert throughout test period; 47% pups also alert compared to 10% in an undisturbed colony.	Van Polanen Petel et al 2008
Australian and NZ fur seals	Montague Island, NSW, Nov 1997–Nov 1998	Observed number of seals 'resting', 'alert', and 'moving to the water' in colonies of different sizes exposed to tour boat disturbance	AFS: As tour boats approached from 100m to 20m, Small colonies (<8 seals) rested less and scanned ~10–30% more than larger colonies (8–31), which in turn rested less and scanned ~10–30% more than largest colonies (>32). NZFS: Scanned generally less in response to tour boat approach than AFS, but small colonies (< 8 seals) scanned up to ~15–20% less than larger colonies (8–31 or >32 seals).	Shaughnessy et al 2008
Grey seals, Cornwall	Traditional haul-out (non-breeding) sites in Cornwall, 2005–12	Leisure craft	In July 2005 a seal flushing incident occurred every 8.5 min. In 2010 this was one incident every 7.5 min and in 2012 every 7.0 min	Cornwall Seal Group 2013[9]

[9] http://www.suesseals.eclipse.co.uk/2013%20routine%20disturbance%20Interupting%20your%20daily%20routine.htm

Appendix 3. Impact of disturbance on other phocid seal species

Species	Location/date	Disturbance source	Impact on seals	Authors
Hawaiian monk seal	Hawaiian islands	Human disturbance and harassment on beach	Monk seals tending to avoid beaches close to human settlements. Eastern Island was occupied by ~ 12 men, and anyone finding a seal drove it into the water. Individual seals and juveniles slow to move away from human approach, and will habituate to non-harassing human presence. A group usually takes to water, with movement by one or two seals in group causing others to awaken, resulting in stampede towards water.	Kenyon & Rice 1959
Hawaiian monk seal	Kure Atoll and Tern Island, NW Hawaiian Islands	Human (and dog) beach activity	During the years when disturbance by US coastguard recreational beach activity was unregulated, seals rarely hauled out. When the station on Kure Atyoll was opened, the annual number of pups born there fell from ~20–30 in the late 1950s to 1–8 by 1988 and pup mortality was very high for those pups born there. The seals avoided their optimum habitat (Green island, with sandy beaches for seal haul-out and birth and shallow, sheltered inshore waters for pups to swim) due to human activity and gave birth instead on sand islets with no sheltered area for pups and frequently washed by large waves. Measures to reduce disturbance were introduced from the late 1970s and breeding seals began to recolonise Green Island.	Gerrodette & Gilmartin 1990
Harp seal	Gulf of St Lawrence, Canada, pupping season 1986–87	Tourist pedestrians on ice	Most mothers left ice when tourists arrived and those that remained did not provide normal care. Maternal attendance to pups reduced, mothers significantly more alert, showed defensive behaviour, and nursing time reduced. Mothers also attempted to lead pups away from tourists. Pups were more active, rested less and actively defended themselves against tourist approach; pups showed 'freeze' response to being approached within 3m or being touched. After disturbance mothers often visited many pups before relocating their own pup. Mothers and pups generally resumed 'normal' behaviour within 1h of tourist departure. Tourist disturbance minimised when tourist behaviour was calm and quiet and did not approach too closely. Weaned pups ceased play-type behaviour when tourists present and continued to show elements of disturbed behaviour for some time after tourists left.	Kovacs & Innes 1990

Southern Elephant seal	Macquarie Isl, Pacific Southern ocean, Sep–Nov 1998	Human presence, including field scientists and tourists	S. Elephant seal populations in Pacific sector of Southern oceans have been in decline for some decades. Therefore human disturbance investigated as a possible factor in the decline. Presence of field scientists resulted in average threefold increase in maternal alertness and decrease in mothers calling. No effect on suckling frequency or duration or agonistic behaviour among mothers recorded. Changes in behaviour transient. No evidence from pup growth that human presence affecting fitness or survival. Decline of Macquarie Isl population thought not to be due to human presence, at least during that period.	Engelhard et al. 2002
Caspian seal (mothers and pups)	Winter ice field in the N. Caspian, Feb 2006–2008	Industrial icebreaker traffic through seal breeding ice	As vessel passed seals, most mothers <100m to side of vessel moved slowly away while their pup followed. However, when <50m to the side of vessel, 27% of 209 pups fell more than 10m behind their mothers , due to mothers moving away too rapidly and in 16% of such records the pups were left >20m behind the mother. Lone Pups <50m almost always moved away and 43% followed a mother-pup pair or another Lone Pup. Thus icebreaker traffic caused a range of disruptive effects to mothers and pups, including displacement from the nursery site, risk of separation, possible difficulty of a returning mother reuniting with her displaced pup and both stress and energy loss to both mother and pup.	Härkönen et al. 2008; Wilson et al. 2008
Weddell seals (adults)	McMurdo Sound, Antarctica, breeding seasons 2006–07	Assessment of repeated handling by researchers	Assessed indicator of overall health in adults from high vs low disturbance areas – no difference in health found. Also measured levels of stress indicators in blood and faecal samples from animals handled twice in <2-week period. No indication of change due to handling.	Mellish et al 2010.

Appendix 4. Impact of disturbance on otariids

Species	Location/date	Disturbance source	Impact on seals	Authors
S. American fur seals (non-breeding)	Cabo Polonio, Uruguay	Pedestrians	'Strong response' (threat posture) from seals when humans crossed 10m threshold. People behaving calmly able to approach with almost no disturbance.	Cassini 2001
NZ fur seal	South Island: 2 populations with high levels of tourist activity Abel Tasman National Park and Kaikoura) and one with no tourists Whakamoa, Banks Peninsula), 2 austral summer seasons (fur seal breeding seasons) 1999–2001	Walking on land, kayaks and motor boats; tourist and experimental disturbance	Baseline 'active behaviour' was 16.6%. Experimental approaches on land (n=334) resulted in 76.6%, by boat (n=935) 36.9% and by kayak (n=2,269) 31%. Seals at Whakamoa showed more behavioural changes and avoidance/aggression than at the tourist sites. 30% seals responded to researcher kayaks at 10m, the current minimum approach distance. A 17% response to approach on land occurred at 20–30m (researchers) and 10–20m (tourists), in kayaks 10–20m (researchers) and 0–10m (tourists) and in boats 20–30m (researchers) and <10m (tourists). Overall seal response greater to land approaches. Some habituation to kayaks at established tourist site. Recommendations to increase minimum distance (currently 10m) to 30m for land approaches, 20m for kayaks and 30m for boats. Response of mothers to disturbance is to move to water while pups run and hide; land-based tourist intrusion at breeding colonies should therefore be prohibited.	Boren et al 2002
Southern fur seal	Peru, 1999	not stated	Currently used breeding sites less likely to have human disturbance	Stevens and Boness 2003
Californian sea lion	Los Islotes, Gulf of California, Mexico, year-round May 2000–2001	Motor launch (48%), yachts (22%), yachts (10%), ships (4%), dinghies (2%). Kayaks (10%) and RIBs (4%) noted during autumn and winter. Activities included sea lion watching	32% human disturbances caused flushing into water. Sea lions did not react to boats >50m away.	Labrada-Martagón et al. 2005

		(30%), snorkelling (27%), scuba diving (26%), kayaking (9%), fishing (5%) and swimming (3%). 71% human disturbances when sources <20m from shore, principally motor launches, scuba tank noise, people screaming, proximity of swimmers and divers.		
Steller sea lion	British Columbia and SE Alaska, May–Aug 2003 & Feb–April 2004	Research scientist disturbance (collecting faecal samples); researchers guided SLs into water using slow arm movements, remained onshore for < 2hr.	Recovery occurred 1–6 days post-disturbance when mean daily counts reached 75–100% pre-disturbance mean.	Kucey & Trites 2006
Australian sea lions	Carnac Nature Reserve, Perth, Western Australia, Oct 2002 to March 2003	Pedestrian approaches from <2.5m to >15m	Sea lions most commonly displayed a low level of alert behaviour ('look' without raising head or sitting up) towards humans, but no correlation between sea lion response and approach distance, even to <2.5m, although some sea lions left the beach.	Orsini et al 2006
Australian and NZ fur seals	Montague Island, new South Wales Nov 1997 to Nov 1998, non-breeding haul-outs including adults of both sexes, juveniles and yearlings	Tour boats and research vessels	AFS: At one colony % probability of continuing to rest decreased from 60–80% when vessels were 100m from shore to 20–40% for vessels at 20m (depending on colony size). Conversely, % probability of seals 'alert' increased from ~20–40%.. Juveniles tended to respond with more active ('alert' and 'moving') behaviour. At other colonies the % probability resting decreased from nearly 100% with vessels at 100m to 10–80% at 20m. NZFS: % probability resting decreased from 100% with vessels at 100m to ~60–90% at 20m. It was therefore recommended that minimum approach distance be set at 40m. Furthermore, boats should not approach upwind of the seals.	Shaughnessy et al 2008
Australian fur seal	Port Phillip Bay, Victoria, Australia, Nov 2007 to Feb 2008	Recreational vessels and swimmers in 'swim-with' tours	No. vessels within 200m of haul-out may have an influence on intra-specific aggressive behaviour; No. swimmers undertaking seal-swim activities was main influence on fur seals hauling out; distance of vessels had a weak effect on no. seals entering water.	Stafford-Bell et al 2010

Californian sea lion	6 islands in Gulf of California, Mexico, 2004–2006	Human exposure, frequency measured at each island location. Exposure defined as any boats or humans within 50m of coastline.	Reproductive rates declined with increasing human exposure. This may be due to physiological stress in response to human presence. No change in neonate body condition and pup growth rate increased – possibly due to reduced competition for food. Human exposure may be selecting for breeding females which tolerate disturbance	French et al. 2011.

Appendix 5. Reviews, management and policy

Purpose	Summary of findings	Authors
To consider whether the impact of human disturbance is effectively measured in species which may not show an overtly strong avoidance response to disturbance	From a conservation perspective, human disturbance is important only if it affects survival or fecundity and hence causes a population to decline. The use of avoidance and other behaviours of disturbance impact may result in confusion when determining conservation priorities. This is because animals subject to disturbance may avoid the disturbance if they have alternative suitable habitat nearby; conversely, animals with no suitable habitat nearby may be forced to remain in the disturbed habitat, even if survival or reproductive success is compromised.	Gill et al. 2001
Minimising disturbance by fence to separate tourists from a non-breeding colony of juveniles and adult male South American fur seals at Cabo Polonio, Uruguay.	Response of seals to tourists was recorded before (1996) and after (2001) erection in 1997 of a 'countryside' fence 1m high, 35m from the watermark. This provided a psychological rather than complete physical barrier between tourists and seals, and relied partly on tourist self-restraint. Tourist approaches were recorded as 1: calm, 2: intermediate and 3: intrusive. Seal responses recorded as 1: retreat, 2: threats toward tourists, 3: attack towards tourists and 4: leaving. Seals in both years responded more to large than to small groups. In 2001 frequency of tourist approaches <10m decreased and approaches >30m increased. Average no. seals responding with threats, attack or leaving decreased after fence erected. No. retreats did not change. Recommendations were that visitors should approach fence calmly and larger tourists groups should be split and separated temporally. Regular monitoring should be carried out with changes to fence location if seals occupy entire area up to an existing fence.	Cassini et al 2004
To describe behaviour of people swimming with fur seals (Port Phillip, Australia) and identify possible hazards for swimmers	51 swims observed, 53% free swim and 47% rope swim. Mean no. swimmers per swim 7.5, mean no. boats 1.1. Possible hazards and need to develop strategies discussed	Scarpaci et al 2005 (abstract only)
To assess the effectiveness of a sanctuary zone relatively tourist-free for Australian sea lions (March–Sept 2006).	A sanctuary zone to exclude tourists was created on 120m of a haul-out beach where the majority (71%) of sea lions had been observed to haul out in a 2003 study. The sanctuary zone was found to be ineffective, with the majority of sea lions using the adjacent 150m zone designated for human recreation. Sea lions spent 4–6% less time resting than their normal 99% time due to greater time responding to human disturbance. The study concluded that the sanctuary zone was not very effective, since many tourists ignored the signs, and the sea lions had in any case changed their preferred area of the beach to the recreational zone (possibly because of seaweed presence or other factors). The study concluded that sanctuary zones in the future should include entire stretches of useable beach to be effective.	Kent & Crabtree 2008

To consider potential impact of jet skis on harbour seal and harbour porpoise commissioned due to investor plans to open part of German Bight to use of jet skis	Review assesses vulnerability of harbour seal (HS) and porpoise (HP) to disruption of natural behaviour and collision risk. Underwater sound from jet ski < RIB < speedboat < fishing vessel. HP avoid fast moving motor boats, showing escape behaviour at 150–233m. Motor boats trigger avoidance more often (100%) than motor yachts (60%) of ferries on regular track (22%). Bottlenose dolphin (BND) response to jet skis more marked than to other vessels. Most groups interrupted their activities, dived and left the area. BND may also respond to boat presence with increased breathing synchrony. An experimental study with a speedboat and a jet ski approaching BND groups found the dolphins changed direction, breathed less often and increased swimming speed. Erratic movement of jet ski provoked largest behavioural change. BND in Aberdeen harbour were more likely to responds negatively to fast boats than slower boats. BND mother-calf pairs in Florida increased dive times in response to jet skis. Escape reaction to boats and jet skis more pronounced in shallow water. In Shetland, faster boats produced greater escape response by HP. Erratic movements at high speed in shallow water increase collision risk. BND injuries from fast motor boats documented. Slower-swimming young animals (and their mothers) most vulnerable to injury. Very young HP and HS common inshore in summer months. Jet ski sound emissions may mask low frequency underwater sounds of HP and HS.	Koshinski 2008
To develop sustainable watersport and tourism activity along Pembrokeshire coastline – measures to protect grey seals cited here	Summary quotation from marine code: *Do not land on pupping beaches from Aug 1–end Nov and do not disturb mothers nursing pups. Avoid creeping up on seals or approaching them bow-on. Keep at least 20m away from seals unless they approach you. Always allow seals an escape route and avoid boxing them in; do not seek to swim with, touch or feed seals. Keep speed below 5 kn on arrival and departure; keep viewing time to 10 min, move away if you observe disturbance such as rapid swimming to and fro, sudden panic diving and re-entry into the water. Moving away can prevent an extended stampede in haul-out areas.* Watercraft advisory (speedboats and jetskis): *do not chase dolphins or porpoises or drive a boat directly towards them.....or change course or speed in a sudden or erratic manner..... avoid dolphins or porpoises with young..... do not approach where there are seals offshore.*	Pembrokeshire Marine Code for watercraft 2008 http://www.pembrokeshiremarinecode.org.uk/wp-content/uploads/2011/02/watercraft.pdf http://www.pembrokeshiremarinecode.org.uk/wp-content/uploads/2011/02/marine_code_details1.pdf
To consider potential impact of water sports and research vessels on conservation objectives of marine reserves	Many marine reserves globally permit water sports with little or no regulation. The most common activities allowed without regulation are swimming (allowed in 63% of reserves), kayaking (allowed in 53%), scuba diving (41%). Jet-skiing, water-skiing and high impact variants of scuba diving, snorkelling, and motorised boating were considered greatest risk to species and habitats within marine reserves. Jet skis and water skiing pose a serious risk of collision to marine megafauna (particularly to seals and small cetaceans in Uk waters). Disturbance due to ongoing activity has severe consequences for animals' resting, feeding and breeding behaviour. Given that speed and	Thurstan et al. 2012

	erratic movement form an inherent part of both jet and water skiing, neither can be compatible with the goals of marine reserves, even at low intensities of use. Motor boats are commonly allowed in marine reserves, but cause stress and disturbance to marine mammals while they are resting or feeding, may affect echolocation and communication and pose a collision risk. Note that these authors consider kayaking and swimming to have generally relatively low wildlife impact, but do not review the literature on seal disturbance.	