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ARTICLE

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Post release monitoring of rehabilitated gray seal pups over large temporal and spatial scales

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Abstract

Wildlife rescue and rehabilitation is used globally to aid the conservation and welfare of marine species, however, post-release monitoring is challenging. Here, long-term, regional postrelease monitoring provides feedback for rehabilitation centers for gray seals (*Halichoerus grypus*). Data from 1,094 rehabilitated gray seals over 19 years across the southwest UK were examined to assess postrelease survivorship and the impact of release site on movements and range. Using flipper tags combined with photo identification, 391 rehabilitated seals (35.7%) were resighted, including 188 seals (17.2%) that were traced back to a specific rehabilitated individual with release data. The maximum monitoring duration for a single rehabilitated seal was 17 years, although the majority (151/188; 80%) were sighted for less than 5 years and 80/188 (43%) were resighted for less than a year. Almost all 188 traced rehabilitated seals ($n = 176$, 93.6%) visited the St Ives Bay Wild Site, yet only half had been released at the adjacent St Ives Bay Release Site. Rehabilitated seals had similar dispersal patterns to their wild conspecifics but over a smaller area. Once released, rehabilitated animals face the same threats as their wild counterparts.

KEYWORDS
post monitoring, release, conservation, gray seal, *Halichoerus grypus*, photo-identification, postweaning dispersal, rehabilitation, release, rescue

1 | INTRODUCTION

1.1 | Wildlife rehabilitation and postrelease monitoring

Wildlife rehabilitation is the treatment and temporary care of injured, diseased, and displaced indigenous animals that are released back into appropriate natural habitats once they are healthy (Miller & Zawistowski, 2012). Thousands of wild animals are rehabilitated and released each year from over 650 wildlife rehabilitation centers in the UK (Kelly et al., 2010). Evidence of the contribution made by wildlife rehabilitation to animal welfare and conservation was reviewed by Mullineaux (2014) who recommended that future policy should include increased veterinary intervention and improved postrelease monitoring. While there is evidence that wildlife rehabilitation can be a valuable tool in terrestrial and marine conservation efforts directly (Cheyne, 2009; Adimey et al., 2012; Saran et al., 2011) and indirectly through education (Feck & Hamann, 2013), there is a lack of scientific research on the survival of rehabilitated individuals with minimal postrelease monitoring (Houser et al., 2011; Kelly et al., 2010; Saran et al., 2011; Wimberger et al., 2010). Postrelease monitoring is essential to inform future decisions about rescue, rehabilitation, and release protocols and the triage, treatment, and welfare of wildlife casualties (Grogan & Kelly, 2013; Moore et al., 2007; Mullineaux, 2014). Postrelease monitoring of mobile marine species is challenging, with a limited number of studies being available for cetacean species (Wells et al., 2013). Most work has been directed at the rehabilitation of pinnipeds, with rehabilitated harbor seals (*Phoca vitulina*), gray seals (*Halichoerus grypus*), Hawaiian monk seals (*Neomonachus schauinslandi*), Steller sea lions (*Eumetopias jubatus*), and cape fur seals (*Arctocephalus pusillus pusillus*) being tracked using satellite transmitters (Gaydos et al., 2013; Greig et al., 2019; Grogan & Kelly, 2013; Hofmeyr et al., 2011; Lander & Gulland, 2003; Lander et al., 2002; Morrison et al., 2012; Norris et al., 2011; Vincent et al., 2002).

1.2 | Gray seals (*H. grypus*) and threats to their survival

Gray seals are a migratory species (Goulet et al., 2001; Kilmova et al., 2014; Sayer et al., 2019; SCOS, 2013) protected under the international Bern Convention (1979) delivered through European and UK legislation (Cronin, 2011; Sayer et al., 2019). Only found in the North Atlantic Ocean, gray seals have two subspecies (northwest and northeast) and the global population is estimated to be 632,000 animals (Bowen, 2016). Based on pup production, approximately 34% of gray seals are found within three nautical miles of the UK coast (Bowen, 2016; SCOS, 2017).

Gray seals face a range of cumulative impacts both from environmental and anthropogenic sources, reducing their chances of survival (Gulland et al., 2018; Kovacs et al., 2012). These include fishery related pressures such as overfishing and depletion of prey fish stocks (Königson, 2011), live entanglement in lost and discarded fishing gear (Allen et al., 2012), and fatal bycatch (Cosgrove et al., 2016; Northridge et al., 2016). These act in addition to a range of other factors, including climate change, habitat loss, disturbance, toxic chemical pollutants, shooting, and culling (Bowen & Lidgard, 2013; Fietz et al., 2016; Nunny et al., 2018; Simmonds, 2017). While data describing the factors affecting the first-year survival of wild gray seal pups (Hall et al., 2001; Peschko et al., 2020) and bycatch mortality of flipper-tagged gray seals along the Norwegian coast exists, (Bjørge et al., 2002) little long-term postrelease monitoring has been conducted on gray seals.

1.3 | Rescue, rehabilitation, and postrelease monitoring of gray seals in the southwest UK

Rescue, rehabilitation, and release of seals in the southwest UK is performed by charities such as British Divers Marine Life Rescue (BDMLR) who primarily undertake rescues, while the Cornish Seal Sanctuary (CSS) and Royal Society for the Prevention of Cruelty to Animals (RSPCA) West Hatch Wildlife Hospital conduct most of the rehabilitation and releases. Although every effort is made to release rehabilitated pups close to their rescue location, this is not always possible given ocean and atmospheric conditions at release time, the implications of unnecessary lengthy travel on the seal's welfare, and the financial cost of moving seals, as well as personnel limitations. Releasing seals from a location different from their rescue may impact intraspecific competition for haul-out space and food resources, as well as alter behavior and haul-out site dynamics (Grogan & Kelly, 2016; Osinga & Hart, 2010).

Postrelease monitoring in pinnipeds may involve satellite telemetry, photo-identification, and flipper tagging. Satellite telemetry provides more detailed data on movement and behavior, including when animals are not visible (Cooke, 2008; Costa et al., 2010; Gales et al., 2009; Kelly et al., 2010; Peschko et al., 2020; Vincent et al., 2016, 2017) for up to a maximum of a year's duration and limited to relatively small sample sizes (Karlsson et al., 2005). Noninvasive photo-identification is used internationally to study the movements, behavior, and ecology of many pinnipeds and other marine species around the world (Baird et al., 2009; Constantine et al., 2012; Cordes & Thompson, 2014; Hiby et al., 2007; Langley et al., 2018; Vincent et al., 2001). Although photo-identification provides longer-term monitoring of larger numbers of seals, the resulting data are more land-based and cannot provide the routes taken between sighting events.

Gray seals released from two rehabilitation centers in the southwest UK were monitored using combined photo identification alongside flipper tag observations by Cornwall Seal Group Research Trust (CSGRT). Using long-term citizen science data at a regional scale, we provide new insights into rehabilitated seal survival, the impacts of release location on an adjacent wild seal site, and postrelease dispersal range.

2 | METHODS

2.1 | Rescue, rehabilitation, and release

Public reports of ill or injured seals are telephoned into BDMLR, CSS, or the RSPCA. Standardized protocols for assessment of pups under a year old (white coated or molted) inform decisions to relocate, euthanize, or rescue. Seals stranded across the southwest UK are transported and admitted to a rehabilitation center such as the CSS in Cornwall or the RSPCA West Hatch Wildlife Hospital in Somerset (Barnett et al., 2001) mostly between September and February. Rescue and release data on all pups admitted for rehabilitation and subsequently released back into the wild from 2000 to 2018 were provided by both rehabilitation centers. Rescued gray seals were assessed as pups based on their pelage, length (<1.4 m; Hewer, 1964), weight, and tooth development. During rehabilitation, seals were tagged with a Dalton Jumbo or Superflexitag plastic tags attached to the webbing of a rear flipper (Figure 1a), each with a unique number (flipper, color, and form dependent on year of admittance and center). To be released, seals passed multiple criteria that include minimum release weights (30 kg), full health assessments, and demonstrate self-sustaining behavior profiles. Release locations were chosen according to the number of seals ready for release, their rescue locations, prevailing sea conditions, and proximity to the rehabilitation center.

2.2 | Photo-identification of seals in the wild

CSGRT monitors seals across 54 haul-out sites (locations were grouped when in close proximity) across the southwest of the UK from north Devon round Cornwall to south Devon and Dorset (418 km shortest straight-line sea

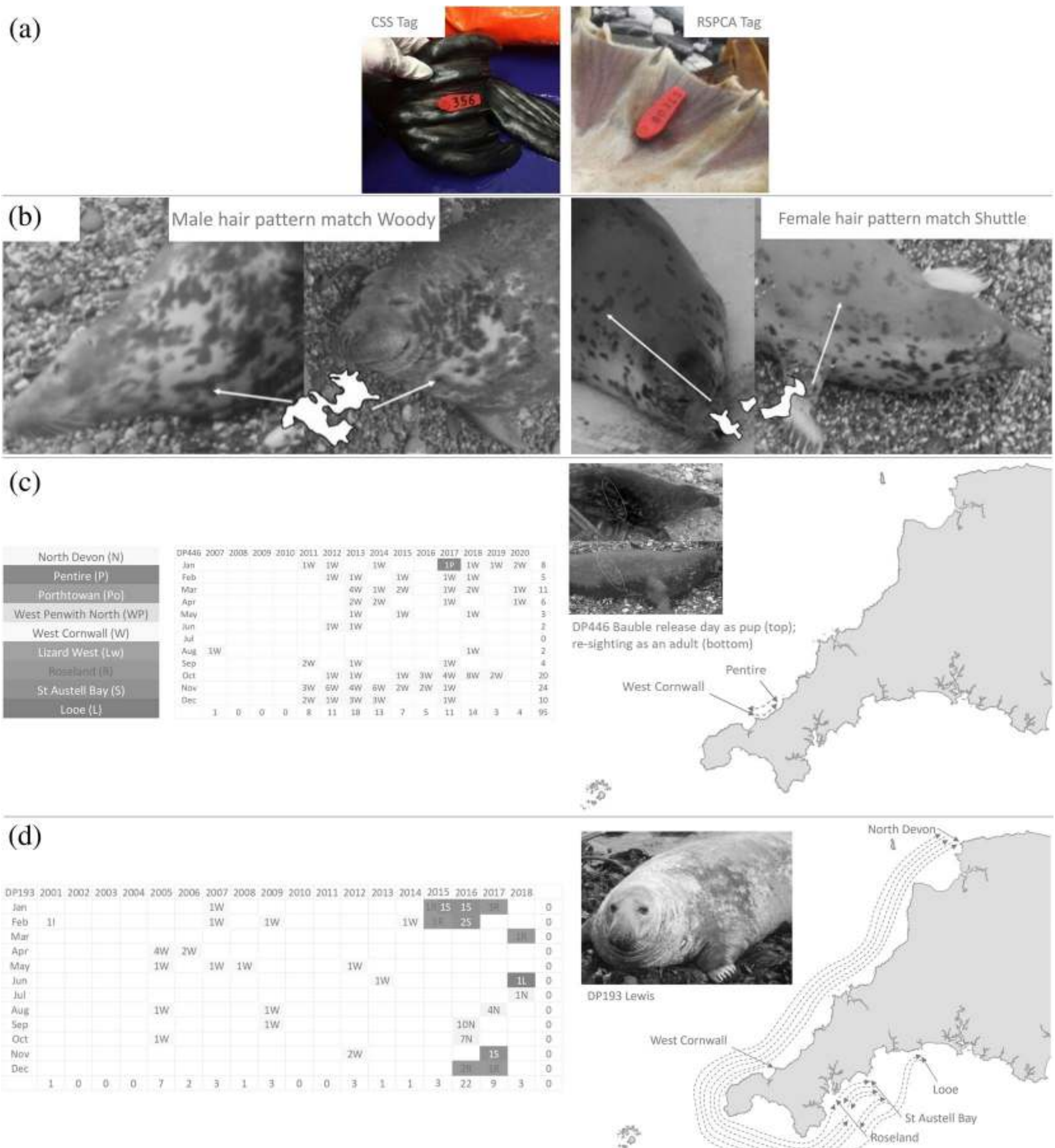

FIGURE 1 (a) Photos showing rear flipper rehabilitation tags. (b) Photo identification hair pattern matches for a male and female. (c) and (d) Examples of individual seal calendars, movement maps and location key reconstructed by photo identification for the two traced rehabbed seals monitored for the longest duration from each rehabilitation center: male RSPCA DP466 “Bauble” (11 years) and male CSS DP193 “Lewis” (17 years). Each arrow's start and end indicate at least one photo identification event. Arrows indicate inferred movements between sites.

distance from headland to headland). Photo-identification of seals was variable through time and space, with some contributors from key haul-out sites providing data either daily (1 site) weekly (20 sites), monthly (7 sites), or quarterly (13 sites), whereas other site surveys (13 sites) were opportunistic. Photo-identification catalogs used in this study were developed independently by the Royal Society for the Protection of Birds (Ramsey Island), The Wildlife Trust of South and West Wales (Skomer Island) in the Pembrokeshire Marine SAC, The Landmark Trust (Lundy Island) in the Lundy Special Area of Conservation, and the Dorset Wildlife Trust. Photo-identification in combination with flipper tag data provided valuable, frequent, and regular postrelease monitoring data about the survival and movements of released rehabilitated pups (Vincent et al., 2002). The same systematic photo-identification methods were used as in Sayer et al. (2019) as shown in Figure 1b–d. This follows a rigorous protocol requiring a minimum of at least five exact pattern matches in the same relative positions, preferably on both sides of the seal and agreed by two experienced photo-identification researchers (see Sayer et al., 2019 for more detail). When sighted for the first time, a tagged seal had its hair pattern photographed and was added to the photo-identification catalog. Henceforth, a combination of photo-identification and tag observations could be used. Tagged seals were assigned to two groups—those where the flipper tag code could be read and traced back to a known individual with specific release data (hereafter referred to as "traced rehabbed seals") and those where the code could not be read, most likely as a result of worn tags or tags only partly visible in the field. Whenever tag codes were illegible, the associated use of hair pattern photo-identification avoided double counting.

2.3 | Data analysis

The number of rehabilitated seals released back into the wild was determined by BDMLR, CSS, and the RSPCA between 2000 and 2018, and annual resighting rates were calculated from CSGRT photo-identification data. For traced rehabbed seals, it was possible to estimate the longevity of their sightings to provide information on postrelease survival. Spearman's rank correlation was used to analyze the relationship between time in rehabilitation and length of postrelease sightings as the data were nonparametric. We present a single case study where a release site (St Ives Bay Release Site in Cornwall) is within 500 m of an important seal haul-out site (St Ives Bay Wild Site) where gray seals are a Site of Special Scientific Interest (SSSI) feature designated by government for their protection (Figure 2). A Pearson's chi-squared test was used to assess the impact of release location by comparing the likelihood of a tagged seal being resighted at the St Ives Bay Wild Site based on where it was released (R Studio Team, 2015). To assess the movement range of rehabilitated compared to wild seals, postrelease movement maps were generated from the resighting locations for traced rehabbed seals set free from the main release location at St Ives Bay Release Site using ArcGIS (ESRI, 2016) and compared to resighting locations for nonrehabilitated seals from the adjacent St Ives Bay Wild Site.

3 | RESULTS

3.1 | Number of rehabilitated seals released, surveys, and resightings rates

Between 2000 and 2018, 1,094 seals were rehabilitated and released at 15 locations (Figure 2). The number released in a given year ranged from 19 in 2004 to 140 in 2018 (Figure 3a). There was a significant increase ($F_{1,17} = 42.86$, $r^2 = 0.72$, $p < .001$) in the number of seals released per year from 2000 to 2018. The step change in numbers of released seals from 2014 reflected a greater number of holding rehabilitation spaces being made available by BDMLR.

In total, 818 seals were released by CSS and 276 by the RSPCA (some seals were originally cared for by the RSPCA and subsequently transferred to CSS for release). A total of 30,323 surveys were completed between 2000 and 2018 across the region, resulting in 56,540 seal identifications (including multiple resightings of individual seals) shown in Figure 3c. Of the 1,094 released seals, 391 (35.7%) were subsequently resighted around the region (compared to resighting rates of 19% of all seals observed at all sites and from a minimum of 27% ($N = 5{,}332$) at St Ives Bay Wild Site to a maximum of 82% ($N = 773$) at Lizard South for systematically surveyed sites. Of the 391 resighted rehabilitated seals, 203 (51.9%) could not be traced back to known rehabilitated individuals (e.g., because the flipper tag numbers were obscured), while 188 (48.1%) were traced back to specific rehabbed seals with associated rescue and release dates. These resighted traced rehabbed seals formed 17.2% of all rehabilitated seals released between 2000 and 2018.

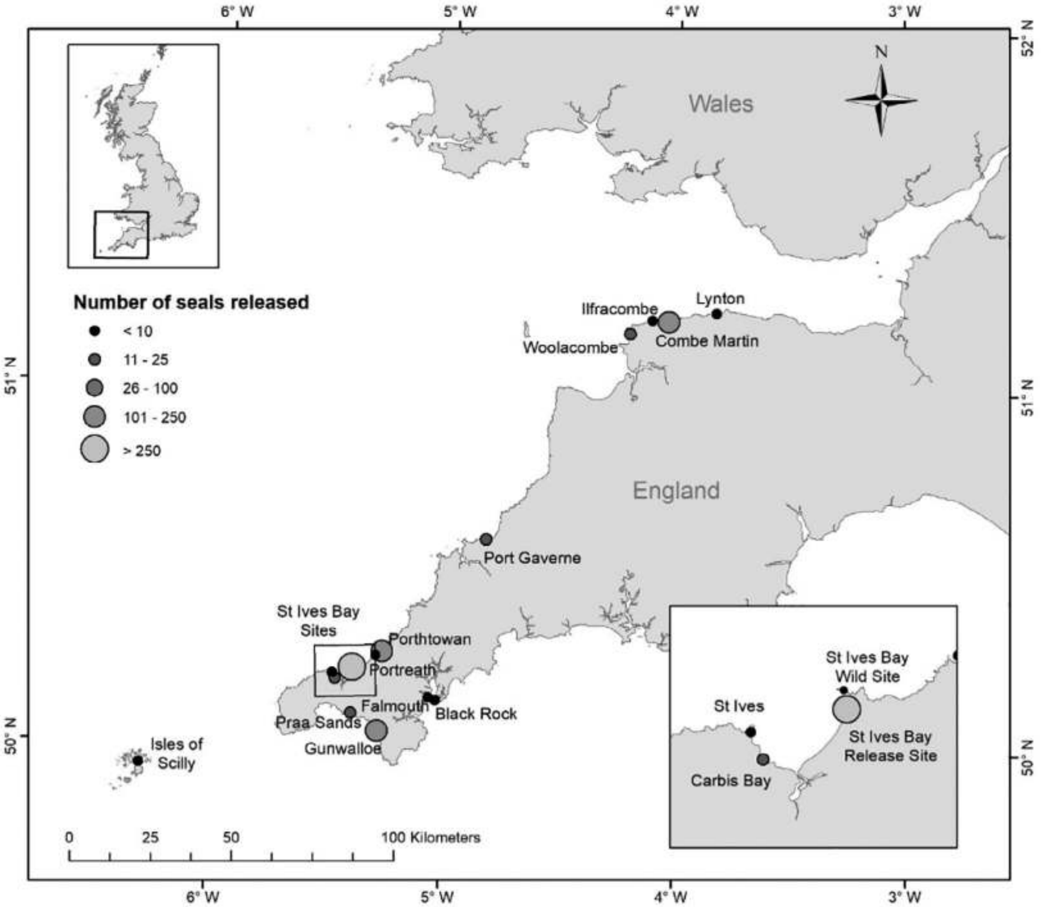

FIGURE 2 Map showing release locations of rehabilitated gray seals ($n = 1{,}094$) in southwest UK. Point size and color show the number of seals released, where larger points with lighter color show more seals released at the location ($n = 15$ release locations).

Most of the 188 traced rehabbed seals were male (60%). Pups spent an average of 113 days in rehabilitation (range from 24 to 487 days). There was no correlation between time in rehabilitation and length of postrelease sightings ($r^2 = 0.123$, p .094). At the RSPCA West Hatch Wildlife Hospital, the average pup weight was 16 kg (range 9–33 kg) on admission and 43 kg (range 32–62 kg) on release. As these data were not available for the Cornish Seal Sanctuary pups, it was not possible to assess any correlation between pup weights and postrelease sightings.

3.2 | Release locations

Release locations ($n = 15$) ranged from southwest Cornwall to north Devon (Figure 2), with the largest number of releases taking place from the St Ives Bay Release Site in northwest Cornwall ($n = 342$, 31.3%), Combe Martin in north Devon ($n = 240$, 21.9%), Gunwalloe in southwest Cornwall ($n = 219$, 20%), and Porthtowan in northwest Cornwall ($n = 177$, 16.2%), with between one and 25 seals released from eleven other locations. Of the 188 traced rehabbed seals, 92 had been released at the St Ives Bay Release Site and 96 had been released from other locations: Black Rock ($n = 1$); Carbis Bay ($n = 4$); Combe Martin ($n = 25$); Falmouth ($n = 1$); Gunwalloe ($n = 20$); Ilfracombe

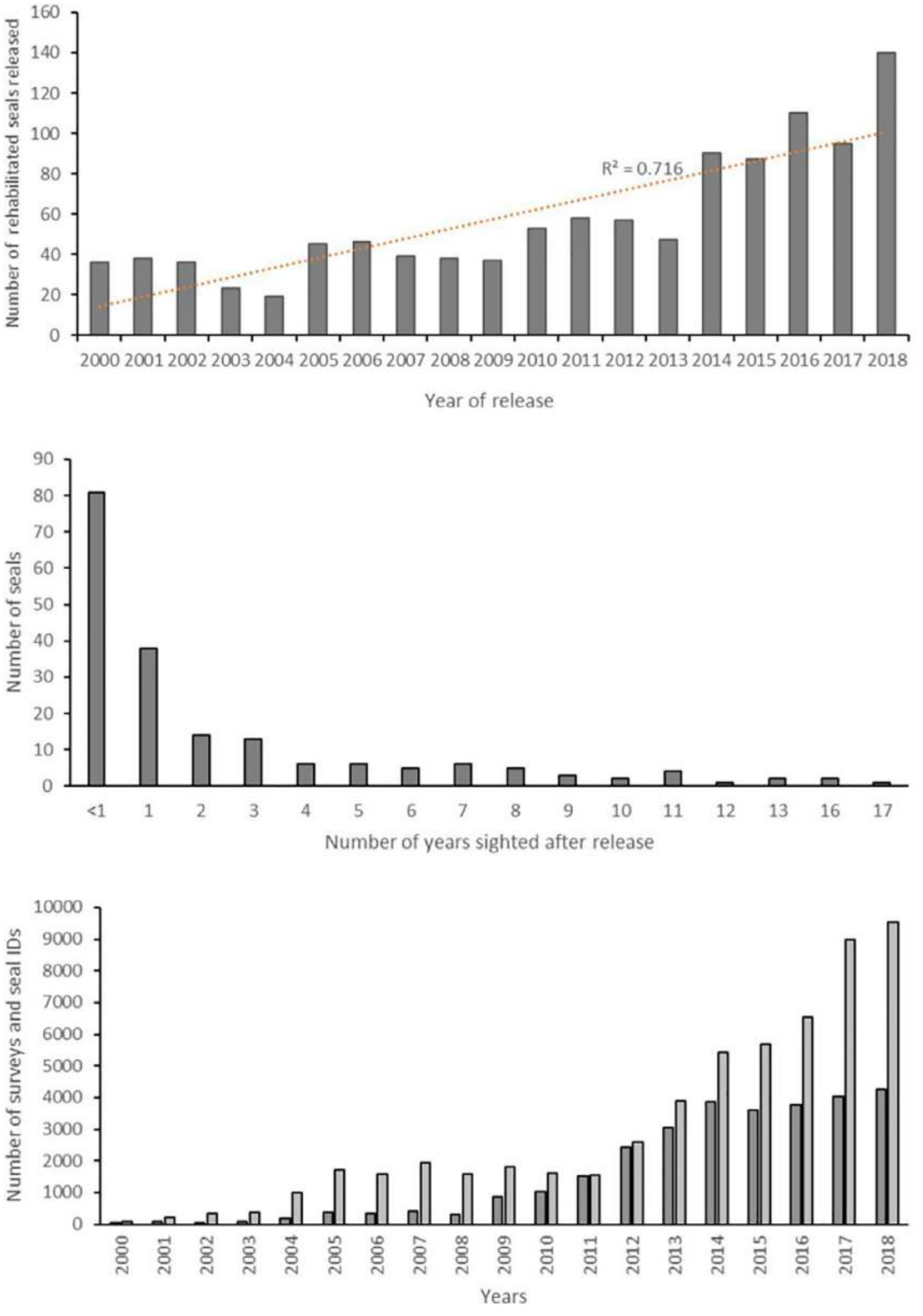

FIGURE 3 Legend on next page.

($n = 1$); Isles of Scilly ($n = 1$); Port Gaverne ($n = 5$); Porthtowan ($n = 33$); Portreath ($n = 3$); St Ives Bay ($n = 1$); and Woolacombe ($n = 1$).

3.3 | Survival based on resightings

Of the 188 traced rehabbed seals, the longest duration between release and the most recent resighting was 17 years (Figure 3b). Eighty percent ($n = 151$) of traced rehabbed seals were resighted for less than five years after release (including 42% [$n = 80$] of the 188 seals that were resighted for less than a year after their release), 13% ($n = 25$) were identified for between 5 and 9 years, 5% ($n = 9$) for between 10 and 14 years, and 2% ($n = 3$) were recorded for 15 years or more. In total at least 20% ($n = 37$) of all rehabilitated seals lived for 5 or more years. For those seals which spent more time back in the wild (released before 2013), the percentage surviving 5 or more years increased to 35% ($n = 37$). These figures represent the minimum number of years that rehabilitated seals survived. Twelve rehabilitated seals were known to have reproduced (eight females having pups and four males successfully beachmastering as dominant males mating with females). In Cornwall, the number of dead gray seal strandings rose from 39 in 2000 to 179 in 2018, with pup mortality peaking between September and February corresponding with peak pupping and postweaning dispersal peaks (Clear et al., 2018). Cornwall Wildlife Trust Marine Strandings Network categorized 2% ($n = 31$) of the 1,603 dead seals in Cornwall between 2000 and 2018 as tagged, rehabilitated seals.

3.4 | Impact of release site on the adjacent wild seal site

Postrelease monitoring of tagged seals revealed movements throughout the region with seals released in north Devon moving to Cornwall and seals released in Cornwall swimming to the Isles of Scilly, Devon, and Wales. For the traced rehabbed seals ($n = 188$), we found no significant association between release site and locations where they were subsequently resighted (Pearson's chi-squared test, $\chi^2 = 3.364$, $df = 2$, $p = .186$; Figure 4). A total of *92* traced rehabbed seals were released at the St Ives Bay Release Site and the majority of these ($n = 89$) were subsequently resighted at the St Ives Bay Wild Site at least once, three seals were seen in the Isles of Scilly and Pembrokeshire in Wales, with some individuals ($n = 15$) seen both at the St Ives Bay Wild Site and elsewhere. Of the 188 traced rehabbed seals released from 13 out of the 15 locations around the southwest peninsula (Figure 2), almost all ($n = 176$; 93.6%) visited the St Ives Bay Wild Site, yet only 50.6% ($n = 89$) of the 176 traced rehabbed seals recorded at the St Ives Bay Wild Site, were known to have come from the adjacent St Ives Bay Release Site (Table 1).

3.5 | Postrelease dispersal range

Wild seals seen at the St Ives Bay Wild Site in the same period (2000–2018) were resighted at multiple locations around Cornwall and other areas within the Celtic Sea (Sayer et al., 2019). Their regional scale movements were compared to those of the traced rehabbed seals from the St Ives Bay Release Site (Figure 5). The number of wild/traced rehabbed seals identified at the geographical extremities of the range visited by traced rehabbed seals were Pembrokeshire 48/2, North Cornwall 70/3, Isles of Scilly 41/7, Lizard 34/1, and St Austell Bay 35/1 seals. Movements of traced rehabbed seals from the St Ives Bay Release Site covered a similar geographical spread to wild seals

FIGURE 3 (a) Barplot with number of rehabilitated gray seal pups released each year from the Cornish Seal Sanctuary and RSPCA West Hatch from 2000 to 2018. (b) Barplot showing the number of years over which traced rehabbed seals were resighted during the survey period 2000–2018. (c) Barplot showing survey effort: unique visits (dark gray) and the number of all gray seals identified (light gray) 2000–2018.

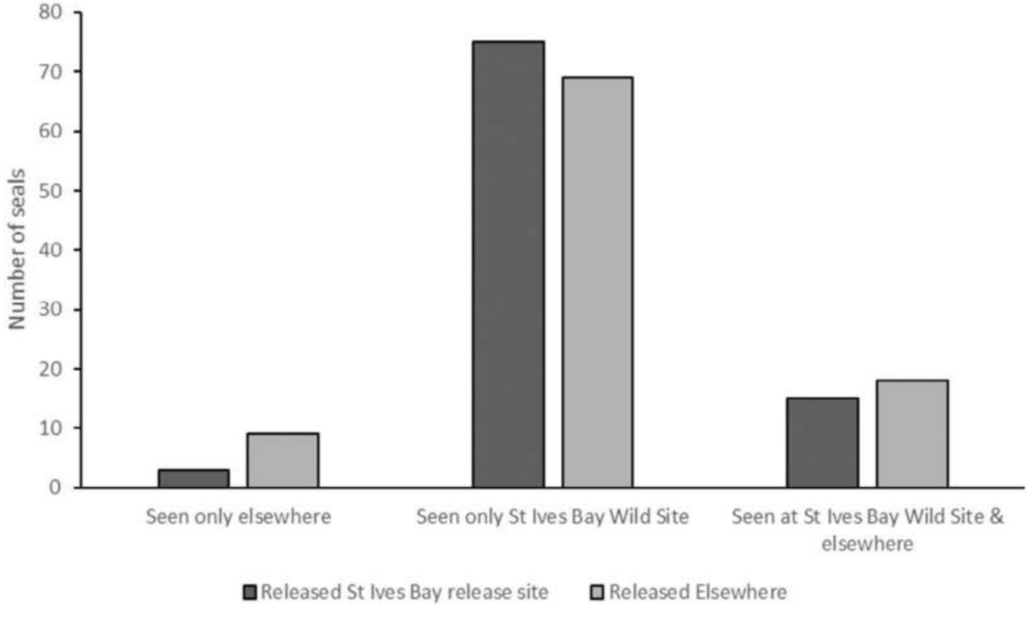

FIGURE 4 Barplot showing the number of traced rehabbed seals ($n = 188$) released from the St Ives Bay Release Site (dark gray bars) and other release locations (light gray bars) seen at the St Ives Bay Wild Site and elsewhere.

TABLE 1 Proportion of traced rehabbed seals identified at St Ives Bay Wild Site described by their release location.

Release location	Km[a]	Total number of traced rehabbed seals seen at St Ives Bay Wild site	% of traced rehabbed seals seen at St Ives Bay Wild site
St Ives Bay Release Site	1	89	50.6
Porthtowan	10	31	17.6
Combe Martin	147	21	11.9
Gunwalloe	65	17	9.7
Other sites	n/a	18	10.2

[a]Approximate shortest distance.

from the adjacent St Ives Bay Wild Site. Both traced rehabbed and wild seals from the St Ives Bay Release and Wild Sites travelled the farthest north to the same two islands of Ramsey and Skomer in Pembrokeshire in Wales (180 km); southwest to the Isles of Scilly (73 km) and south to Lizard Point (73 km). The farthest movements differed to the northeast and southeast, with wild seals travelling farther to north and south Devon (150 km and 206 km, respectively) than traced rehabbed seals (north Cornwall and St Austell Bay; 75 km and 122 km). Figure 5 shows wild seals spreading out across a larger area (22,779 km^2) compared to the traced rehabbed seals (11,398 km^2).

4 | DISCUSSION

4.1 | Resightings rates

Over the 19-year monitoring period, a relatively high proportion of rehabilitated seals were resighted (35.7%) across the region in comparison to previously published studies, for example, Vincent et al. (2002), reported a resightings

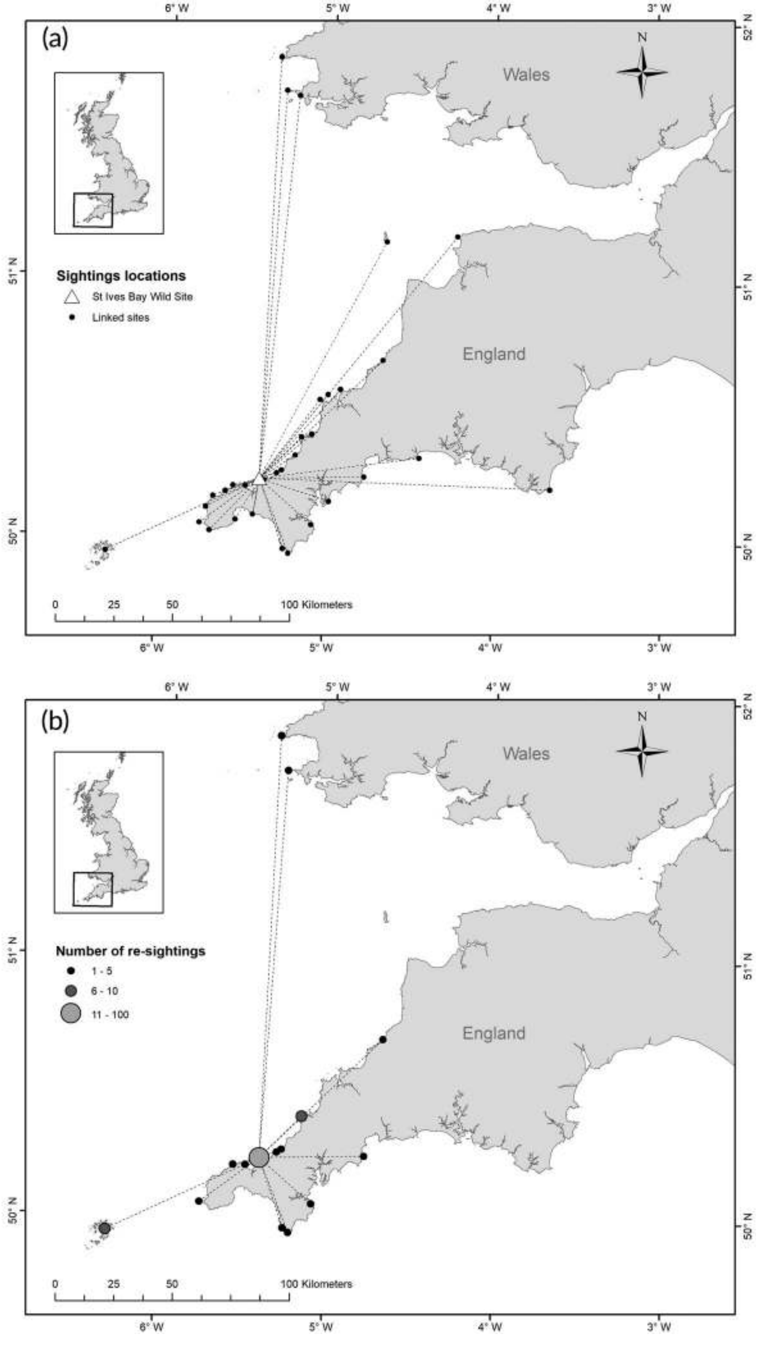

FIGURE 5 (a) Map showing resightings locations where all nonrehabilitated and identified seals seen from St Ives Bay Wild Site have been reidentified (Sayer et al., 2019). (b) Map showing resighting locations for traced rehabbed seals ($n = 92$) released at the adjacent St Ives Bay Release Site.

rate of 14% of gray seals that were fitted with flipper tags over a 10-year period Brittany, France. Similar studies on other pinniped species reveal variable resighting rates that appear to be affected by monitoring duration and species range (Baker & Thompson, 2006; Hofmeyer et al., 2011; McMahon et al., 2003; Osinga & Hart 2010) as well as population size, behavior, and ecology of the species concerned. For example, high resighting rates (85%) of Hawaiian monk seals over 20 years of monitoring could be a result of a small population (Gilmartin et al., 2011; Littnan et al., 2015) with a limited geographical range (Baker & Thompson, 2006), whereas harbor seals have a much larger geographical range, even within subpopulations (Lowry, 2016), which may explain lower resighting rates (7.9%) arising from movements (Osinga & Hart, 2010).

Despite CSGRT's considerable increase in survey effort shown in Figure 3c, resighting and reidentification of individual tagged seals may be hindered by multiple factors. These include tag loss with remnant tag holes having been observed by CSGRT and others (McMahon & White, 2009; Oosthuizen et al., 2010; Stobo & Horne, 1994); tag deterioration over time through wear and tear (including color and code fade); the size of a seal's flipper becoming proportionally larger with age in relation to the tag; the seal and/or tag position in the photo, and whether the seal was on land or in the sea (which may conceal the tag); as well as the quality of resightings photos, dependent on camera equipment and distance between surveyor and seal. The time of year (with respect to the annual molt) and the moisture level of the seal's hair can also make its patterns less distinct (Forcada & Aguilar, 2000; Hiby et al., 2007; Schop et al., 2017). Using a combination of flipper tagging and associated photo-identification can improve the chances of resighting and reidentifying an individual seal. In other studies, a large number of tagged seals are resighted but cannot be traced back to a specific individual (Smout et al., 2011; Walker et al., 2012). In particular, tags appear to be most legible in the first 1–3 years postrelease, and if pelage patterns can be associated with their flipper tag number during this time, the seals can be reliably identified by photo-identification even after the tag becomes illegible.

Despite these difficulties, proportionally more rehabilitated seals were resighted (35.7%) than wild, non-rehabilitated seals (27%) at the St Ives Bay Wild Site (Sayer et al., 2019). Identifications of wild or tagged seals cannot be guaranteed even when the seals are present given the challenging nature of this work. It is likely that the dual method of color flipper tagging in combination with photo-identification of hair patterns is more effective, leading to a higher identification rate for this subgroup of seals. Despite this, 703 (64.3%) of the released rehabilitated seals and similarly high proportions of wild seals were not known to be resighted. The multiple, confounding factors discussed above make the identification of any gray seal around the coast challenging and will have reduced the chances of any identified seal being classified as a rehabilitated one. The sex bias towards males in rehabilitated seal pups (60%) reflects the proportion of males recorded in adults (64%) sighted across the region (Sayer et al., 2019). An unknown proportion of the tagged seals in this region could have traveled to and from other parts of the Celtic Sea, not visited CSGRT's routinely monitored sites nor been identified by CSGRT's photo-identification teams or partners. In addition to the 2% dead rehabilitated seals confirmed by the Cornwall Wildlife Trust Marine Strandings Network others, like their wild counterparts, will have been impacted by cumulative environmental and anthropogenic threats and not survived.

4.2 | Survival

When seals are successfully reidentified in the wild and traced back to a specific seal that has been rehabilitated, individual ages and survival can be accurately determined and reported to rehabilitation centers. Multiple factors have been demonstrated to impact the survival of rehabilitated mobile species, for instance: body condition index at admission for penguins (Morten et al., 2017); the availability of adequately equipped care facilities, trained personnel, refined care protocols and release conditions for oiled gulls (Golightly et al., 2002); duration of intervention for cetaceans (Wells et al., 2013) and prerelease wild behavior training increased the independent survival of bats (Kelly et al., 2008). As no correlation was found between time in rehabilitation and postrelease sightings, further studies are needed to assess any potential correlation between postrehabilitation survival and other factors, such as weight, age on admission, body condition, rehabilitation capacity and treatment protocols. Juvenile gray seals have high mortality rates of up to 75% in the first 18 months (Davies, 2001). Coupled with poorer diving ability and greater curiosity, young seals have a higher susceptibility to bycatch if interacting with fishing gear (Bjørge et al., 2002). Seals in the southwest UK have the second highest rate of entanglement for any phocid species anywhere in the world (Allen et al., 2012) and chemical pollution is also a documented risk (Bonner, 1970). Three rehabilitated seals were subsequently recorded as becoming entangled postrelease. In addition, increasing frequency of storms in the south of the UK (Alexander et al., 2005) may result in more pups becoming separated from their mothers, or being seriously injured and killed by storm surges and big swells (Anderson et al., 1979; Boness et al., 1995; Härkönen et al., 2007), resulting in insufficient fat stores on weaning to survive (French et al., 2011; Hall et al., 2001; Hoover-Miller et al., 2013; Pomeroy et al., 1999). Young seals are disproportionally affected by anthropogenic disturbance (Bellman et al., 2019; Osinga et al. 2012) wasting critical energy reserves that are already delicately balanced.

Cumulative impacts will likely result in the increase in strandings of dead gray seals recorded around Cornwall (Clear et al., 2018) as well as the increased number of seal pups in distress, underweight, in ill health, or found in unsuitable, public locations around the UK. For example, in the southwest UK, a record 471 reported stranding events were recorded by British Divers Marine Life Rescue (BDMLR) in the 2017/2018 pupping season (Jarvis, 2019), although not all calls result in rescues. Without accurate data on wild seal mortality, it is impossible to comparably assess the rehabbed survival recorded here with their wild counterparts.

4.3 | Network of seal sites, seal movements, and range

Gray seals have a predominantly solitary nature when at sea and have shown varied individualized movements (Huon et al., 2015; Matthiopoulos et al., 2004; Peschko et al., 2020; Sayer et al., 2019), indicating that each rehabilitated seal will likely differ in its range and movement patterns after release (Austin et al., 2004; Hall et al., 2001; Peschko et al., 2020). Gray seal pups are known to travel long distances during their first few weeks after weaning, exploring habitat in their search for profitable foraging areas (Peschko et al., 2020) and site fidelity is displayed in adulthood at least at some locations (Bjørge et al., 2002; Jenssen et al., 2010; Vincent et al., 2002). In this study, traced rehabbed postrelease seals moved up to 150 km from their release site.

A large majority (93.6%, $n = 176$) of the traced rehabbed seals were seen at the St Ives Bay Wild Site at least once as they undertook their postweaning dispersal around the Celtic Sea. The high number of identifications at the St Ives Bay Wild Site could result from natural postweaning exploratory behavior; a higher and more consistent survey effort, over the longest time period at this site or could reflect the critical importance of this site for seals. Flipper tags were more visible on land so were more likely to be resighted at haul-outs such as this. However, these seals had been released from multiple locations around Cornwall and Devon, indicating that proximity of release location did not appear to impact where subsequent sightings occurred. This is reinforced by the finding that seals released at the St Ives Bay Release Site appeared to be no more likely to be seen at the St Ives Bay Wild Site than seals released from locations elsewhere (Figure 4), some of which were a considerable distance away (150 km in north Devon). Many wild seals also link multiple sites around the Celtic Sea to the St Ives Bay Wild Site (Figure 5). This reinforces the importance of this habitat for seals and supports the designation of the St Ives Bay Wild Site as a SSSI where gray seals are included within the citation (Natural England, 2019). This has implications for management of the area to prevent any seal disturbance, injury, or death from anthropogenic activities such as from recreation, tourism, fishing, and extractive seabed activities (Maxwell et al., 2013; Tin et al., 2014). Traced rehabbed seals released at the St Ives Bay Release Site appeared to show a similar range of movement (apart from visiting north and south Devon) to wild seals identified at the adjacent St Ives Bay Wild Site.

4.4 | Postrelease monitoring methods

Understanding survival of rehabilitated seals is often carried out via postrelease satellite tracking (Dendrinos et al., 2007; Gaydos et al., 2013; Lander & Gulland, 2003; Norris et al., 2011), however, due to cost and practical limitations, sample sizes are usually low and can only provide data for less than a year of the animal's life due to annual molt cycles (Culloch et al., 2015; Fedak et al., 1983), so may not show a true representation of released individuals, as well as longevity of survival (Hart & Hyrenbach, 2009; Moore et al., 2007). Although not providing the same detail of movement data, the application of complementary flipper tagging and photo-identification methods in this study successfully enabled a large number of rehabilitated individuals to be monitored over the long-term and at least 17 years.

4.5 | Implications for rehabilitation

Postrelease monitoring of rehabilitated seal pups continues to provide important feedback to rehabilitation centers, as well as provide information about seal behavior and movements that are crucial to informing management practices at sensitive and protected seal sites (Grogan & Kelly, 2013). The data available begin to address the impact of a release site on an important adjacent wild seal site. Landowner permission is required for release, so it is key to understand the impact that releases may have on nearby wild seal sites. For future studies it would be helpful to know whether rehabilitated seals are representative of their wild counterparts in terms of their subsequent movements. It is important to improve the evidence base available to inform good practice guidelines for wildlife rehabilitation and release (Stidworthy, 2016), refining protocols and saving time, travel, resources while minimizing animal stress, which can be considerable (Houser et al., 2011; Leighton et al., 2008). In the southwest UK, rehabilitation centers have successfully released seals that can survive for up to 17 years and demonstrate similar movement and dispersal patterns to their wild conspecifics albeit over a smaller area. For future studies it is helpful to know whether rehabilitated seals could be representative of their wild counterparts. Survival success is not the only outcome from rehabilitation centers and many centers perform other conservation roles for their target species, for example human impact reduction, habitat restoration and public education (Moore et al., 2007). The centers in this study both raise awareness of marine conservation issues regionally and globally. As with photo-identification, individual seal rehabilitation stories have the power to create personal connections with wildlife and encourage us all to take action to help resolve marine threats. Wild animal rehabilitation is key to supporting conservation efforts not just as an end in itself, but with the potential to reduce environmental pressures created by global population increases and economic growth—in terms of energy consumption, industrial and agricultural production, transportation, mining and tourism choices (Aslan et al., 2018). For a seal near death at rescue, any intervention will likely make a difference to its welfare or chances of survival. The resightings in the present study suggest that gray seals can be appropriately rehabilitated, released, and survive. However once released, rehabilitated animals face the same environmental and anthropogenic threats as their wild counterparts, so public, stakeholder, and statutory agency engagement is key to reducing postrelease impacts, particularly in developing nations (Houser et al., 2011; Karesh, 1995).

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