NIWA
Taihoro Nukurangi

Effects of ships lights on fish, squid and seabirds

Prepared for Trans-Tasman Resources Ltd

Updated November 2015

Authors/Contributors:
David Thompson

For any information regarding this report please contact:

David Thompson
Scientist
Marine Ecology
+64-4-386 0300
d.thompson@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
301 Evans Bay Parade, Greta Point
Wellington 6021
Private Bag 14901, Kilbirnie
Wellington 6241
New Zealand

Phone +64-4-386 0300
Fax +64-4-386 0574

NIWA Client Report No:	WLG2013-16
Report date:	April 2013
NIWA Project:	TTR11301

26 November 2015 4.48 p.m.

Contents

Figures

Reviewed by

Alison MacDiarmid

....

Approved for release by

Julie Hall

....

Formatting checked by

...

Executive summary

Trans-Tasman Resources Ltd (TTR) proposes to extract offshore iron sands from the seabed in the South Taranaki Bight (STB). This will entail use of a large (330 m long) processing vessel that will be permanently moored over the extraction site 22-40 km offshore in water depths of 25-45 m. The vessel will be permanently crewed and will be a 24/7 operation requiring deck lighting at night for safe operation. These deck lights, in combination with standard navigational lights, will locally increase the presence of artificial nocturnal lighting posing a theoretical threat to marine life.

This report drew upon the published literature to consider the effects of nocturnal artificial light on fish, squid and seabirds, taking into account the likely light regime on the TTR iron sand processing vessel.

While it is well known that light attracts many species of fish, squid and seabirds, and that this characteristic has been employed for centuries in order to enhance catches of species for human consumption, there is a general paucity of quantified information on the non-targeted use of light at night and its effect on these marine groups.

Overall, artificial nocturnal light generally attracts all three groups of marine animals to a certain extent. The attractiveness of light is not universal across these marine species: for example, the majority of diurnally-active seabirds appear not to exhibit marked attraction to artificial light, whereas light can potentially be a problem for nocturnal species.

For fish and squid, any effects of the iron sands extraction vessel as a source of artificial nocturnal light are likely to be very localised and centred on the vessel itself: some species of both groups could potentially aggregate in the water column close to the vessel, but these effects are highly unlikely to have any measurable population level impact on the attracted species.

Similarly for seabirds it is potentially possible that the vessel's lights may attract nocturnal species, particularly in poor weather, but the remoteness of the area of operation from major seabird breeding colonies and relatively standard mitigation protocols would also suggest that any effect would be highly unlikely to have any measurable population level impact on the attracted seabird species.

Information relating to TTR's additional scientific work undertaken since 2014 has been provided and the conclusions is this report remain valid.

1 Introduction

The increase in anthropogenic nocturnal light has been the subject of several recent reviews (for example, Longcore & Rich 2004, Depledge et al. 2010). Depledge et al. (2010) noted that light pollution of the sea has become a significant issue in only the last 50-80 years and further suggested that 'light pollution occurs when organisms are exposed to light in the wrong place, at the wrong time, or at the wrong intensity'. Indeed, lights from light-fishing fleets were one of the four principal sources of anthropogenic light identified by Elvidge et al. (2001) in 1994-95 (the other three being human settlements and urbanisation, gas flares and forest fires) using remotely-sensed satellite data. Hölker et al. (2010) argued that light pollution should be considered as a threat to biodiversity. Furthermore, the behaviour, reproduction and survival of a wide range of marine animals (from invertebrates through to fish, marine reptiles, seabirds and marine mammals) have been shown to be influenced by artificial lights (Verheijen 1985). The attraction of some species of squid and fish to light is utilised by commercial fisheries which employ relatively powerful directed light in order to enhance captures of target species. Generally, other vessels do not intend to attract marine animals specifically with lights, but sometimes seabirds, for example, can become disorientated in ships' lights and collide with the ship.

Trans-Tasman Resources Ltd (TTR) proposes to extract offshore iron sands from the seabed in the South Taranaki Bight (STB). This will entail use of a large processing vessel that will be permanently moored over the extraction site 22-40 km offshore in water depths of 25-45 m. The vessel will be permanently crewed and will be a 24/7 operation requiring deck lighting at night for safe operation. These deck lights, in combination with standard navigational lights, will locally increase the presence of artificial nocturnal lighting posing a potential threat to marine life.

This report drew upon the published literature to consider the effects of nocturnal artificial light on fish, squid and seabirds, taking into account the likely light regime on the TTR iron sand processing vessel.

2 Fish

Like other marine animals that respond to light, marine fish evolved in environments and habitats where moon light, star light and bioluminescence were the only nocturnal lighting sources. Artificial nocturnal light has modified the intensity, spectra, frequency and duration of light reaching and penetrating the oceans' surfaces. Artificial night lighting influences fish foraging and schooling behaviour, spatial distribution, predation risk, migration and reproduction. These effects can combine to affect community ecology of fishes and both their prey and predators (see Nightingale et al. 2006).

An artificial nocturnal lighting source from a vessel operating in a relatively fixed location, or over a relatively small spatial extent could potentially affect marine fish in a number of ways. Firstly, small fish species may be attracted to an artificial light source because the artificial light also serves to focus their marine plankton prey, a long-established effect (Spooner 1933). Small prey fish species are more likely to school, a common anti-predator response (for example Magurran & Pitcher 1987), under elevated light conditions (Major 1977, Ryer & Olla 1998). Indeed, purse seine fishers for small clupeids in the Mediterranean Sea use lights at night to attract and concentrate fish (Arcos & Oro 2002). Many larger, predatory fish species rely on visual cues to locate and capture prey. Visual foraging models predict that due to a decreased prey encounter rate, predator foraging success declines with either increasing water turbidity or decreasing light levels (for example, Aksnes & Giske 1993, Utne-Palm 2002). Batty et al. (1990) found that in herring *Clupea harengus* feeding increased with prey density in high light intensity experiments, while under dark conditions increased prey levels failed to elicit a similar increased feeding response. Similar results have also been reported for walleye pollock *Theregra chalcogramma* and sablefish *Anoplopoma fimbria* (Ryer & Olla 1999). Therefore, artificial nocturnal lighting, emanating from a source such as a vessel, has the potential to alter the feeding behaviour of predatory fish, attracted by aggregations of smaller prey species and enhanced foraging conditions, these smaller prey species in turn attracted by increased concentrations of plankton drawn to the elevated light environment.

Becker et al. (2013), working in an estuarine environment, conducted night-time surveys of the fish community directly adjacent to a floating restaurant that illuminated the water next to the man-made structure. The light regime was controlled, either on or off, in order to examine fish abundance and behaviour. Becker et al. (2013) found clear differences in the abundance of fish between the two light treatments: large predatory fish (> 500 mm total length) increased in abundance when the lights were on, their behaviour changed to maintain their position within the illuminated area and the abundance of small shoaling fish also increased with the lights on. The artificial nocturnal lighting created conditions that potentially benefitted larger, piscivorous fish through both the concentration of prey and an enhanced foraging environment for visual predators (Becker et al. 2013).

The study of Becker et al. (2013) is a very rare example of experimental research into the *in situ* effects of artificial nocturnal lighting on the abundance and behaviour of fishes. While that study was undertaken in an estuarine environment, the Bushmans Estuary in South Africa, the findings are perhaps applicable to a slow moving or near-static vessel operating at night and casting light downwards into the immediate water column. Such enhanced light conditions have the potential to attract both plankton and planktivorous fish, the latter more likely to shoal in the relatively high-light conditions, and in turn attract larger, predatory fish, drawn close to the vessel by prey aggregations and improved foraging conditions. Any such effects of vessel lights are very likely to be extremely localised, operating to the extent of nocturnal illumination of the water surrounding the boat. While local (i.e. immediately around the vessel) increases in fish abundances may occur, it is highly likely that any such attraction of fish towards the vessel will have a negligible effect at a population level, certainly at the level of the species potentially involved.

3 Squid

It is well known that many species of pelagic squid are attracted to light. A definitive explanation for this behaviour remains elusive, but is exploited by several fisheries around the world. Most light-fishing vessels are jiggers, catching squid with jigs (lures armed with an array of barbless hooks) fished in series on lines using automatic machines. Squid are attracted to jigging vessels with an array of powerful metal halide, incandescent lights. Large industrial offshore jigging vessels use about 150 lamps (Rodhouse et al. 2001), mostly white with a few green lights interspersed (Inada & Ogura 1988). In New Zealand, a light-fishing squid jigging fishery targets the squids *Nototodarus sloanii* and *N. gouldi*, but is small in comparison to the sub-Antarctic squid trawl fishery, and extremely small compared to the light-fishing fleet targeting the squid *Todarodes pacificus* in waters of the Kuroshio Current and seas to the northeast of Taiwan (Rodhouse et al. 2001). Indeed, such is the brightness of nocturnal light emitted from the major squid light-fishing fleets, the extent and scale of these fisheries can be mapped remotely using satellite imagery (for example, Rodhouse et al. 2001, Waluda et al. 2002, 2004) (see Figure 3-1).

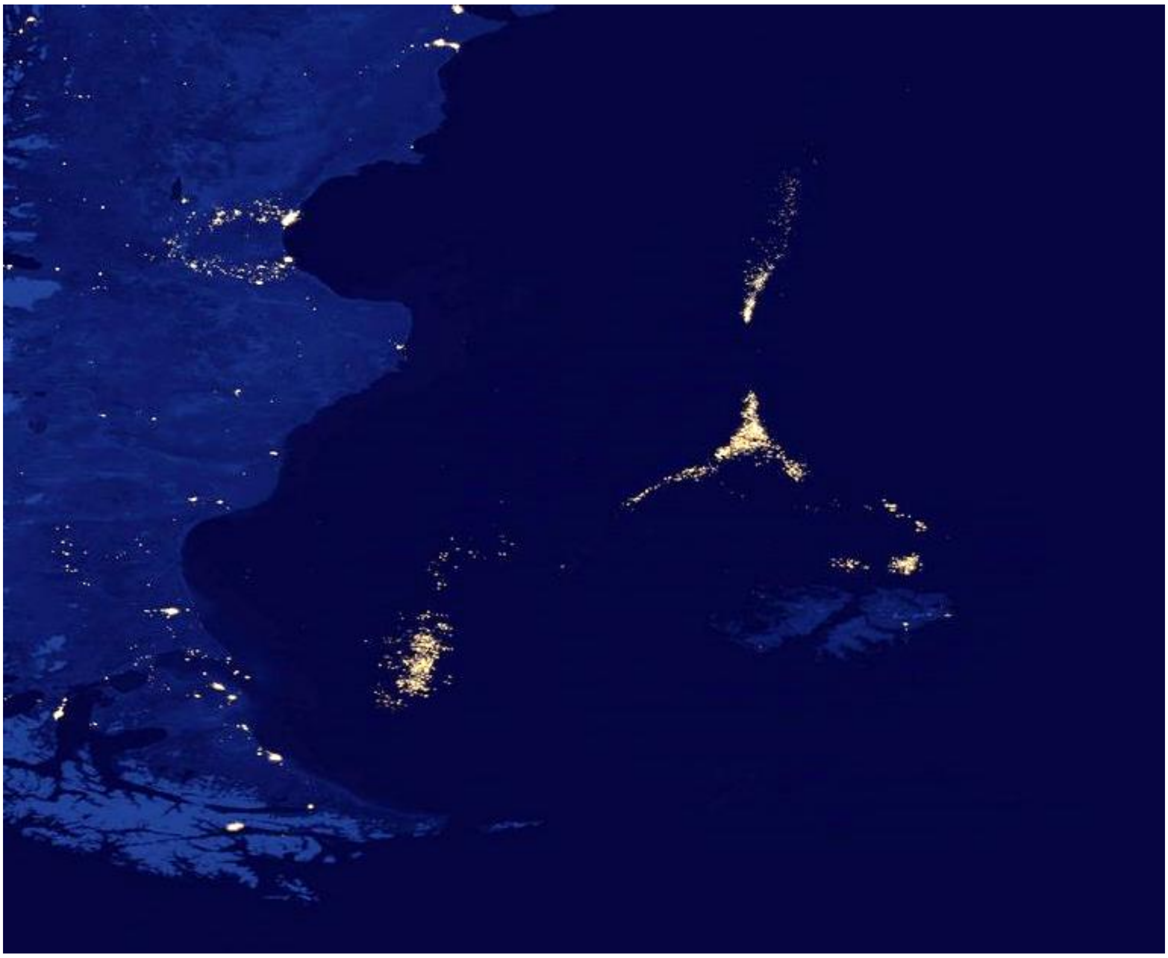

Figure 3-1: Satellite image of lights from squid boats at night along the disputed maritime border between Argentina and the Falkland Islands. (Image April 2012, NASA Earth Observatory).

Apart from the use of large, powerful lights to attract squid to fishing vessels, there is a paucity of published information on the effects of other sources of artificial nocturnal light on squids. Cephalopods (squids and octopuses) were not considered in a relatively recent review of the ecological consequences of artificial night light (Rich & Longcore 2006). It is possible that lights on a vessel as part of the operation under consideration here could attract squid. However, given the intensity and power of lights used on commercial light-fishing squid jigging vessels any effect of the relatively modest lights on the iron sands extraction vessel will likely be relatively small.

4 Seabirds

In the absence of artificial light, nocturnal oceans are essentially dark, flat environments negotiated by seabirds, many of which are active at night, in part to avoid diurnal predators. Additionally, many species of seabirds feed at night on vertically-migrating and bioluminescent prey (for example, Weimerskirch et al. 2005). Many nocturnally-active seabird species tend to be attracted to artificial light sources: this attraction has been suggested to result from their adaption to feed on bioluminescent prey (Imber 1975) or from their use of specific star patterns (Reed et al. 1985) – in these cases, artificial light might be perceived to be attractive, super-normal stimuli (Montevecchi 2006). Indeed, humans used to exploit birds by lighting fires to specifically attract nocturnal birds (Maillard 1898, Murphy 1936, Murie 1959), and it has long been recognised that birds can become disorientated and sometimes killed at night in the presence of relatively strong, artificial light (for example, Allen 1880, Brewster 1886).

Seabirds can be impacted directly by a wide range of artificial light sources within marine environments: seabirds can be attracted to and collide with lighthouses (Evans 1968, Crawford 1981, Verheijen 1981, Roberts 1982), coastal resorts and other urban lighting (Reed et al. 1985, Telfer et al. 1987, Le Corre et al. 2002), offshore hydrocarbon platforms (Ortego 1978, Hope-Jones 1980, Tasker et al. 1986, Baird 1990, Wiese et al. 200, Burke et al. 2005) and commercial fishing vessels and other boats using lights (Dick & Donaldson 1978, Ryan 1991, Arcos & Oro 2002, Black 2005, Merkel & Johansen 2011).

In the case of vessels, it is generally well known that nocturnal bird strikes tend to occur when bright, artificial light sources are used at times of poor visibility, typically during bad weather, often angled outwards or upwards from the vessel and when the vessel is relatively close to large breeding aggregations of seabirds (rather than further offshore). However, there are relatively few sources of quantified information relating to seabird strikes on vessels. In extreme cases, the number of birds hitting the vessel and accumulating on decks can threaten the stability of the vessel (Dick & Donaldson 1978). During the course of a single night in Alaska, an estimated 6,000 crested auklets *Aethia cristatella*, or approximately 1.5 metric tonnes, were on board the FV *Lynda* at once, blocking scuppers and causing the vessel to list. The vessel was relatively close to land and operating bright fishing lights (Dick & Donaldson 1978). Ryan (1991) reported an average of 131 seabirds of eight species, all relatively small nocturnal petrels and shearwaters, found on board the commercial lobster vessel FV *Hekla* each night over a two week period when operating close to islands in the Tristan da Cunha archipelago. There was a great deal of variation around this average figure, with very few birds landing on the vessel on clear, moonlit nights, and approximately 900 birds on board on very misty nights (Ryan 1991). Black (2005) reported on two events which involved relatively large numbers of seabirds: on a single night the MV *Dorada* collected 899 seabirds in the South Atlantic, mainly prions diving petrels and storm petrels, of which 215 were killed. Similarly, the MV *Aurora Australis* collected over 200 dead birds (again mainly prions and diving petrels) while anchored at night near Heard Island (Black 2005). In both cases, the weather was calm but misty and overcast with poor visibility and in both cases the vessels were operating a variety of deck and other lighting. Additionally, both incidents occurred in relative close proximity to nesting seabird colonies. Similarly, Merkel & Johansen (2011) noted that significantly more birds were recorded striking a range of vessel types in Greenland waters when visibility was poor compared to when visibility was moderate or better.

One potential indirect effect of nocturnal artificial light from a vessel, especially if the sources of light directed the light downwards into the water, could be to aggregate prey species attracted by the relatively bright lights (see section on fish and squid above). Seabirds as predators may, in turn, be attracted to these prey aggregations, and indeed, many species of marine birds have been recorded feeding in artificial nocturnal lighting, including at offshore fishing vessels and hydrocarbon platforms (for example, Hope-Jones 1980, Burke et al. 2005). In such situations, seabirds may actually benefit to some extent from artificial nocturnal light sources.

Black (2005) suggested that bird strikes on vessels operating in the southern oceans are an almost nightly occurrence, but that the level of mortality is generally low. Perhaps this low mortality level could at least partly explain why relatively few birds are returned from commercial fishing vessels operating in New Zealand waters – the only reported source of seabird-vessel strike information available for the region. New Zealand Government observers are placed on a selection of commercial fishing vessels and are tasked with returning all seabirds incidentally killed as part of fishing operations, including seabirds killed as a result of deck strike: over five recent years (fishing years 2005-06 to 2009-10, where the start of the year begins at 1 October and finishes 30 September of the following year) of seabird bycatch returns there were deck strike totals of 8 (of 369 total returns), 3 (of 324), 6 (of 251), 7 (of 381) and 7 (of 280), respectively (Thompson 2009, 2010a, 2010b, 2010c, in press). While light was not specifically identified as the cause of the deck strikes on fishing vessels it is highly likely to have been the key attractant for most of the seabirds affected. It is noteworthy that the vast majority of the New Zealand deck strikes were of small petrels, typically diving petrels, prions and storm petrels, but also including *Pterodroma* petrels. Nevertheless, at least for those fishing vessels carrying an observer, the numbers of seabirds killed through deck strike are remarkably low.

In New Zealand there are a number of codes of practice and policies relating to vessel lighting and seabirds, mainly with a commercial fishing vessel focus. For example the Protected Species Handbook for Inshore Vessels produced by the Department of Conservation notes that 'vessel lighting is shielded to avoid shining out onto the longline and illuminating the baits' and that 'stern lights are switched off when not required for shooting and hauling as lights attract seabirds to the vessels'. Similarly, the Department's code of best practice for surface longliners notes that 'vessel lighting needs to be shielded to avoid shining out onto the longline, less light on the longline helps reduce the ability of the bird to see the baited hooks' and that 'the stern deck lights should be switched off when not required for shooting and hauling as lights attract seabirds to the vessel'. The Department's draft Sub-Antarctic and Kermadec Regional Coastal Plan (see http://www.doc.govt.nz/getting-involved/consultations/current/proposed-regional-coastal-plan-kermadec-and-subantarctic-islands/), Policy 18 states 'to encourage anyone undertaking activities in the coastal marine area of the islands to minimise the generation of artificial light (excluding lights required for navigation) and, where use of artificial light cannot be avoided, to remedy or mitigate the effects as far as practicable'.

Black (2005) suggests several recommendations for reducing light-induced seabird mortality on vessels, including:

- alerting vessels to the risk associated with the use of ice-lights and other deck lighting, particularly on nights when visibility is poor and in the vicinity of seabird islands.
- black-out blinds should be mandatory on all portholes and windows with external lighting kept to the minimum required for safe navigation and operation of vessels.
- keeping deck lights to a minimum when at anchor or close inshore overnight.
- providing information on how to treat and release birds found on deck.

To the recommendations of Black (2005) it could be added that deck lights should, wherever possible and practicable be directed downwards and shielded to reduce as much horizontal light shining out from the vessel as possible. Interestingly, there is some experimental evidence that red filters in front of white floodlights on tall structures reduced avian casualties by up to 80% (Wiese et al. 2001), and on an offshore gas-production platform in the North Sea, the use of green lights, instead of the usual white lights, reduced the number of birds that were disorientated (Poot et al. 2008). Poot et al. (2008) found no difference in the effects of red and white light, and it should be noted that their results related mainly to migrating passerine birds, shorebirds, ducks and geese. It would be very worthwhile experimenting with light colours and their attractiveness to seabirds.

The area of operation under consideration here is relatively far from the closest seabird breeding colonies – the nearest offshore islands are the Nga Motu/Sugar Loaf Islands group off New Plymouth, which support perhaps a few tens of thousands of breeding pairs of seabirds, including grey-faced petrel *Pterodroma macroptera* and common diving petrel *Pelecanoides urinatrix*. It is therefore likely that a vessel used as part of the iron sands extraction process operating an artificial light protocol that incorporates the recommendations noted in this report will pose a relatively low risk to seabirds utilising the marine environment.

5 Conclusions

While it is well known that light attracts many species of fish, squid and seabirds, and that this characteristic has been employed for centuries in order to enhance catches of species for human consumption, there is a general paucity of quantified information on the non-targeted use of light at night and its effect on these marine groups.

Overall artificial nocturnal light generally attracts all three groups of marine animals to a certain extent. The attractiveness of light is not universal across these marine species: for example, the majority of diurnally-active seabirds appear not to exhibit marked attraction to artificial light, whereas light can potentially be a problem for nocturnal species.

For fish and squid, any effects of the iron sands extraction and processing vessel as a source of artificial nocturnal light are likely to be very localised and centred on the vessel itself: some species of both groups could potentially aggregate in the water column close to the vessel, but these effects are highly unlikely to have any measurable impact on the attracted species.

Similarly for seabirds it is potentially possible that the vessel’s lights may attract nocturnal species, particularly in poor weather, but the remoteness of the area of operation from major seabird breeding colonies and relatively standard mitigation protocols, which should be applied wherever possible, would also suggest that any effect would be highly unlikely to have any measurable impact on the attracted seabird species.

Information relating to TTR's additional scientific work undertaken since 2014 has been provided and the conclusions is this report remain valid.

6 Acknowledgements

I thank Alison MacDiarmid for reviewing the draft report and translating it to the required format.

7 References

Aksnes, D.L.; Giske, J. (1993). A theoretical model of aquatic visual feeding. *Ecological Modelling 67*: 233-250.

Allen, J.A. (1880). Destruction of birds by light-houses. *Bulletin of the Nuttall Ornithological Club 5*: 131-138.

Arcos, J.M.; Oro, D. (2002). Significance of nocturnal purse seine fisheries for seabirds: a case study off the Ebro Delta (NW Mediterranean). *Marine Biology 141*: 277-286.

Baird, P.H. (1990). Concentrations of seabirds at oil-drilling rigs. *Condor 92*: 768-771.

Batty, R.S.; Blaxter, J.H.S.; Richard, J.M. (1990). Light intensity and the feeding behaviour of herring, *Clupea harengus*. *Marine Biology 107*: 383-388.

Becker, A.; Whitfield, A.K.; Cowley, P.D.; Jarnegren, J.; Naesje, T.F. (2013). Potential effects of artificial light associated with anthropogenic infrastructure on the abundance and foraging behaviour of estuary-associated fishes. *Journal of Applied Ecology 50*: 43-50.

Black, A. (2005). Light induced seabird mortality on vessels operating in the Southern Ocean: incidents and mitigation measures. *Antarctic Science 17*: 67-68.

Brewster, W. (1886). Bird migration. Part 1. Observations on nocturnal bird flights at the light-house at Point Lepreaux, Bay of Fundy, New Brunswick. *Memoirs of the Nuttall Ornithological Club 1*: 5-10.

Burke, C.M.; Davoren, G.K.; Montevecchi, W.A.; Wiese, F.K. (2005). Seasonal and spatial trends of marine birds along offshore support vessel transects and at oil platforms on the Grand Banks. In: Armsworthy, S.l.; Cranford, P.J.; Lee, K. (eds.) Offshore oil and gas environmental effects monitoring: approaches and technologies, pp. 587-614. Battelle Press, Columbus, Ohio, USA.

Crawford, R.L. (1981). Bird kills at a lighted man-made structure: often on nights close to a full moon. *American Birds 35*: 913-914.

Depledge, M.H.; Godard-Codding, C.A.J.; Bowen, R.E. (2010). Light pollution in the sea. *Marine Pollution Bulletin 60*: 1383-1385.

Dick, M.H.; Donaldson, W. (1978). Fishing vessel endangered by crested auklet landings. *Condor 80*: 235-236.

Elvidge, C.D.; Imhoff, M.L.; Baugh, K.E.; Hobson, V.R.; Nelson, I.; Safran, J.; Dietz, J.B.; Tuttle, B.T. (2001). Night-time lights of the world: 1994-1995. *Journal of Photogrammetry and Remote Sensing 56*: 81-89.

Evans, G. (1968). Lighthouse report 1968. *Bardsey Observatory Report 16*: 49-53.

Hölker, F.; Wolter, C.; Perkin, E.K.; Tockner, K. (2010). Light pollution as a biodiversity threat. *Trends in Ecology and Evolution 25*: 681-682.

Hope-Jones, P. (1980). The effect on birds of a North Sea gas flare. *British Birds 73*: 547-555.

Imber, M.J. (1975). Behaviour of petrels in relation to the moon and artificial lights. *Notornis 22*: 302-306.

Inada, H.; Ogura, M. (1988). Historical changes of fishing light and its operation in squid jigging fisheries. *The Report of the Tokyo University of Fisheries 24*: 189-207.

Le Corre, M.; Ollivier, A.; Ribes, S.; Jouventin, P. (2002). Light-induced mortality of petrels: a 4-year study from Réunion Island (Indian Ocean). *Biological Conservation 105*: 93-102.

Longcore, T.; Rich, C. (2004). Ecological light pollution. *Frontiers in Ecology and Environment 2*: 191-198.

Magurran, A.E.; Pitcher, T.J. (1987). Provenance, scholl size and the sociobiology of predator evasion behaviour in minnow schools. *Proceedings of the Royal Society B 229*: 439-465.

Maillard, J. (1898). Notes on the nesting of the fork-tailed petrel (*Oceanodroma furcata*). *Auk 15*: 230-233.

Major, P.F. (1977). Predator-prey interactions in schooling fishes during periods of twilight: a study of the silverside *Pranesus insularum* in Hawaii. *Fishery Bulletin 75*: 415-426.

Merkel, F.R.; Johansen, K.L. (2011). Light-induced bird strikes on vessels in southwest Greenland. *Marine Pollution Bulletin 62*: 2330-2336.

Montevecchi W.A. (2006). Influences of artificial light on marine birds. In: Rich, C.; Longcore, T. (eds.) Ecological consequences of artificial night lighting, pp. 94-113. Island Press, Washington, USA.

Murie, O.J. (1959). Fauna of the Aleutian Islands and Alaska Peninsula. *U.S. Fish and Wildlife Service North American Fauna 61*: 1-364.

Murphy, R.C. (1936). *Oceanic birds of South America*. Macmillan, New York, USA.

Nightingale, B.; Longcore, T.; Simenstad, C.A. (2006). Artificial night lighting and fishes. In: Rich, C.; Longcore, T. (eds.) Ecological consequences of artificial night lighting, pp. 257-276. Island Press, Washington, USA.

Ortego, B. (1978). Blue-faced boobies at an oil production platform. *Auk 95*: 762-763.

Poot, H.; Ens, B.J.; de Vries, H.; Donners, M.A.H.; Wernand, M.R.; Marquenie, J.M. (2008). Green light for nocturnally migrating birds. *Ecology and Society 13*: 47.

Reed, J.R.; Sincock, J.L.; Hailman, J.P. (1985). Light attraction in endangered procellariiform birds: reduction by shielding upward radiation. *Auk 102*: 377-383.

Rich, C.; Longcore, T. (eds.) (2006). Ecological consequences of artificial night lighting. Island Press, Washington, USA.

Roberts, P. (1982). Birds at Bardsey lighthouse 1982. *Bardsey Observatory Report 26*: 33-34.

Rodhouse, P.G.; Elvidge, C.D.; Trathan, P.N. (2001). Remote sensing of the global light-fishing fleet: an analysis of interactions with oceanography, other fisheries and predators. *Advances in Marine Biology 39*: 261-303.

Ryan, P.G. (1991). The impact of the commercial lobster fishery on seabirds at the Tristan da Cunha islands, South Atlantic. *Biological Conservation 57*: 339–350.

Ryer, C.H.; Olla, B.L. (1998). Effect of light on juvenile walleye pollock shoaling and their interaction with predators. *Marine Ecology Progress Series 167*: 215-226.

Ryer, C.H.; Olla, B.L. (1999). Light-induced changes in the prey consumption and behaviour of two juvenile plankivorous fish. *Marine Ecology Progress Series 181*: 41-51.

Spooner, G.M. (1933). Observations on the reactions of marine plankton to light. *Journal of the Marine Biological Association of the UK 18*: 385-438.

Tasker, M.L.; Hope-Jones, P.; Blake, B.F.; Dixon, T.; Wallis, A.W. (1986). Seabirds associated with oil production platforms in the North Sea. *Ringing and Migration 7*: 7-14.

Thompson, D.R. (2009). Autopsy report for seabirds killed and returned from observed New Zealand fisheries: 1 October 2005 to 30 September 2006. DOC Marine Conservation Services Series 2. Department of Conservation, Wellington. 35p.

Thompson, D.R. (2010a). Autopsy report for seabirds killed and returned from observed New Zealand fisheries. 1 October 2006 to 30 September 2007. DOC Marine Conservation Services Series 3. Department of Conservation, Wellington. 37p.

Thompson, D.R. (2010b). Autopsy report for seabirds killed and returned from observed New Zealand fisheries. 1 October 2007 to 30 September 2008. DOC Marine Conservation Services Series 5. Department of Conservation, Wellington. 33p.

Thompson, D.R. (2010c). Autopsy report for seabirds killed and returned from observed New Zealand fisheries. 1 October 2008 to 30 September 2009. DOC Marine Conservation Services Series 6. Department of Conservation, Wellington. 37p.

Thompson, D.R. (in press). Autopsy report for seabirds killed and returned from observed New Zealand fisheries. 1 October 2009 to 30 September 2010. DOC Marine Conservation Services Series. Department of Conservation, Wellington.

Telfer, T.C.; Sincock, J.L.; Bryd, G.V., Reed, J.R. (1987). Attraction of Hawaiian seabirds to lights: conservation efforts and effects of moon phase. *Wildlife Society Bulletin 15*: 406-413.

Utne-Palm, A.C. (2002). Visual feeding of fish in a turbid environment: physical and behavioural aspects. *Marine and Freshwater Behaviour and Physiology 35*: 111-128.

Verheijen, F.J. (1981). Bird kills at tall lighted structures in the USA in the period 1935-1973 and kills at a Dutch lighthouse in the period 1924-1928 show similar lunar periodicity. *Ardea 69*: 199-203.

Verheijen, F.J. (1985). Phtopollution: artificial light optic spatial control systems fail to cope with incidents, causations, remedies. *Experimental Biology 44*: 1-18.

Waluda, C.M.; Trathan, P.N.; Elvidge, C.D.; Hobson, V.R.; Rodhouse, P.G. (2002). Throwing light on straddling stocks of *Illex argentinus*: assessing fishing intensity with satellite imagery. *Canadian Journal of Fisheries and Aquatic Science 59*: 592-596.

Waluda C.M.; Yamashiro, C.; Elvidge, C.D.; Hobson, V.R.; Rodhouse, P.G. (2004). Quantifying light-fishing for *Dosidicus gigas* in the eastern Pacific using satellite remote sensing. *Remote Sensing of Environment 91*: 129-133.

Weimerskirch, H.; Gault, A.; Cherel, Y. (2005). Prey distribution and patchiness: factors in foraging success and efficiency of wandering albatrosses. *Ecology 86*: 2611-2622.

Wiese, F.K.; Montevecchi, W.A.; Davoren, G.K.; Huettmann, F.; Diamond, A.W.; Linke, J. (2001). Seabirds at risk around offshore oil platforms in the north-west Atlantic. *Marine Pollution Bulletin 42*: 1285-1290.