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Impacts of purse-seine fishing on seabirds and approaches to mitigate bycatch

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SUMMARY

This review summarises existing literature relating to the interaction of seabirds with purse seine fishing gear and operations. The review details management of seabird interactions in purse seine fisheries via two case studies. Mitigation measures that have been developed to reduce the mortality of seabirds, are also described, and mainly flow from one fishery.

Bycatch in purse seine fisheries includes a range of marine organisms. The bycatch species groups most susceptible to mortality in purse seine fisheries are dolphins, marine turtles, and sharks as well as non-target fish species. We found limited evidence of seabirds being recorded as bycatch in purse-seine gear and this finding has been reported by others. However, large numbers of flesh-footed shearwaters (*Ardenna carneipes*) have been caught in a Western Australia purse seine fishery targeting pilchards. This bycatch occurs in a particular area of the Fishery during a period of the year when fishing effort is in close proximity to breeding grounds and when birds are provisioning chicks, demonstrating that in certain situations and times, seabirds will interact freely with purse-seine gear.

Fishing at night and spatial closures would likely eliminate seabird bycatch in the fishery, as the reported bycatch has a spatial and temporal component. Close attendance of purse seine gear during setting and retrieval during daylight operations allows the implementation of mitigation measures, particularly tow-off procedures that remove folds in the nets that can entrap birds as well as water spraying. These measures have been successful in greatly reducing seabird interaction levels in the Western Australian fishery.

Efectos de la pesca con red de cerco en las aves marinas y estrategias para mitigar la captura secundaria

RESUMEN

La presente revisión resume la documentación existente sobre la interacción de las aves marinas con las operaciones y los artes de pesca asociados a las pesquerías con red de cerco. La revisión detalla la ordenación de las interacciones de las aves marinas en las pesquerías con red de cerco a través de dos estudios de caso. También se describen las medidas de mitigación que han sido elaboradas para reducir la mortalidad de las aves marinas, y surgen sobre todo de una pesquería.

La captura secundaria en las pesquerías con red de cerco abarca una gama de organismos marinos. Los grupos de especies afectadas por la captura secundaria que son más susceptibles a morir en las pesquerías con red de cerco son los delfines, las tortugas marinas y los tiburones, al igual que las especies de peces no objetivo. Encontramos escasa evidencia de que se hayan registrado aves marinas como parte de la captura secundaria realizada con red de cerco, información coincidente con los datos notificados por terceros. Sin embargo, se han capturado grandes cantidades de fardelas de patas pálidas (*Ardenna carneipes*) en una pesquería con red de cerco de Australia Occidental dirigida a la sardina. Esta captura secundaria se produce en un área particular de la pesquería durante un período del año en que el esfuerzo pesquero se aproxima a los sitios de cría y en que las aves alimentan a sus pichones, lo que demuestra que algunas veces, en ciertas situaciones, las aves marinas interactuarán libremente con la red de cerco.

Es posible que la pesca noctura y las vedas espaciales pongan fin a la captura secundaria de aves marinas en la pesquería, dado que la captura secundaria notificada presenta un componente espacial y temporal. La proximidad de redes de cerco durante el calado y las operaciones de extracción realizados durante las operaciones diurnas permiten que se implementen medidas de mitigación, en particular de los procedimientos de remolque que evitan tanto la formación de los pliegues de las redes en los que pueden quedar atrapadas las aves, como la pulverización de agua. Estas medidas han sido exitosas a la hora de lograr una reducción significativa en los niveles de interacción de las aves marinas en la pesquería de Australia Occidental.

Impacts de la pêche à la senne coulissante sur les oiseaux marins et méthodes d'atténuation des captures accessoires

RÉSUMÉ

Cet examen synthétise les documents d'information existants relatifs à l'interaction des oiseaux de mer avec les engins de pêche et les opérations à la senne coulissante. Il explique en détail la gestion des interactions des oiseaux marins dans la pêche à la senne coulissante grâce à deux études de cas. Les mesures d'atténuation qui ont été élaborées afin de réduire la mortalité des oiseaux de mer sont également décrites et proviennent principalement d'une pêcherie.

La capture accessoire dans la pêche à la senne coulissante concerne une série d'organismes marins. Les groupes d'espèces victimes de captures accessoires les plus exposés à la mortalité dans la pêche à la senne coulissante sont les dauphins, les tortues de mer et les requins, ainsi que des espèces de poisson non ciblées. Nous avons trouvé peu d'éléments indiquant que des oiseaux marins sont enregistrés en tant que captures accessoires d'engins à senne coulissante, et d'autres études ont mené aux mêmes conclusions. Cependant, un grand nombre de puffins à pieds pâles (*Ardenna carneipes*) a été capturé dans la pêche à la sardine pratiquée à la senne coulissante en Australie-Occidentale. Cette capture accessoire se produit dans une région de pêche particulière à une époque de l'année où les opérations sont très proches des sites de reproduction et lorsque les oiseaux alimentent leurs oisillons. Cela prouve que les oiseaux de mer interagiront librement avec les engins à senne coulissante dans certaines situations et à certaines périodes.

La pêche de nuit et les fermetures spatiales élimineraient probablement la capture accessoire d'oiseaux marins, puisque les captures accessoires rapportées comportent des éléments spatial et temporel. La surveillance de l'engin à senne coulissante pendant la mise à l'eau et le virage lors des opérations de jour permet de mettre en œuvre des mesures d'atténuation, notamment des procédures de traction qui retirent les plis des filets pouvant piéger des oiseaux, ainsi que l'arrosage. Ces mesures ont réussi à réduire considérablement les niveaux d'interaction des oiseaux marins dans la pêche en Australie-Occidentale.

1. INTRODUCTION

Scope

This paper is an abstract from a global review on the impacts on non-target species by vessels using purse seine fishing gear targeting pelagic fish (Finley et al., 2014). Here we have contained our review to seabirds only, and removed all reference to bycatch of other species.

The aim of this paper is to:

1. Review global literature on the direct impact of purse seine fishing operations on seabird species.
    - For the purposes of this research 'direct interactions' include:
        a) any interactions with fishing operations or gear (including net feeding, feeding on discards or wastes);
        b) any physical contact (including collisions with vessels or gear); and
        c) bycatch (netted or entangled) which can result in injury or mortality;
2. Report on the availability and effectiveness of bycatch mitigation devices or management measures, including codes of practice, to reduce or minimise interactions between purse seine fishing operations and seabirds.

2. PREPARATION OF THE REVIEW

Relevant information from global fisheries was reviewed and compiled into a literature review. Where appropriate, the review highlights the availability and effectiveness of bycatch mitigation devices or management measures for the relevant protected species/species groups to reduce or minimise interactions between purse seine fishing operations, transshipment and/or mothership operations.

Fisheries were identified as operating purse vessels and relevant professionals contacted to obtain information. Information and data from fisheries that utilise purse seine gear was compiled into a fishery description, including (but not limited to-):

- Description of fishery, including fishing areas, gear,
- Nature and extent of interactions with protected species and bycatch problem(s),
- Technical details of mitigation devices and the efficacy of the device, and
- Management requirements

In addition to the comprehensive review of published literature, a number of global experts were contacted regarding purse seine fisheries. Management and research considerations that are relevant to the application of bycatch mitigation measures in purse seine fisheries are also suggested.

3. RESULTS OF THE REVIEW

A. INTRODUCTION TO PURSE SEINE FISHING

Purse seines are fishing nets designed to catch schooling fish (Figures 1 and 2).

There are two different methods of purse seining: the one-boat and the two-boat system. Although both have their advantages and disadvantages, purse seining with a single boat is now considered

more economical in large fishing operations (Gabriel *et al.* 2005). In two-boat purse seining, two boats operate together with each carrying about half the gear. The two boats set each part simultaneously beginning with the middle of the seine net. In one-boat purse-seining for the larger fishing operations, the gear is set around a fish shoal beginning with the launch of a net-skiff, which is a smaller vessel attached to one end of the net. The main vessel then moves to encircle the fish school, laying out the net as it goes, until it returns to the position of the net-skiff (Gabriel *et al.* 2005). Smaller vessels using smaller nets encircle the fish shoal with the seine net without the assistance of a net-skiff.

The top of the net is hung on a float line lined with buoys. The bottom is attached to a lead line, which usually consists of a steel chain with steel rings, known as "purse rings", and is attached below the chain. The purse line that runs through the purse rings is made of steel and allows the pursing of the net. Modern purse seiners are equipped with a power block to purse the lead line after fish are inside of the net. Descriptions of the gear and operations can be found in Sacchi (2008). Further information is also available at www.fao.org/fishery/geartype/249/en and video materials in www.tunaseiners.com (Hall and Roman 2013). Once encirclement is finished, the end of the net that stayed attached to the skiff is transferred aboard the purse seiner and the two ends of the purse line cable are hauled with the winch as quickly as possible in order to close the net at its bottom (this is called 'pursing' as it is similar to pulling the draw string of an old-fashioned purse) (Figure 3). Until the purse seine is closed, encircled animals can still dive below the net or the purse seine vessel and escape. During pursing, and especially when there is a current, the skiff is attached to the starboard side of the vessel, where it can pull it away from the net in order to prevent the purse seiner from drifting over the net. The pursing operation may take, for large tuna purse seines, about 15 to 20 minutes (Hall and Roman 2013). While the purse is being closed, use of green dye bombs and speed boats may be used to create wash and keep fish away from edges (e.g. Secretariat to the Pacific Community video 'Introduction to Purse Seine Fishing' http://www.youtube.com/watch?v=hBo-6F49ej8).

For large tuna purse seine vessels, when most of the purse seine has been retrieved and the fish have been grouped within a restricted area along the portside of the vessel, the fish are harvested from the purse seine net using a large scoop net or "brailer" (brailing operation) or by using fish pumps:

- **Brailler:** The capacity (usually 2–8 tonnes) of the brailer and the amount of fish loaded may result in different conditions for the individuals brought on board and, for those released, may have varying impact on their post-release survival (Hall and Roman 2013). Brailling purse seines with scoop nets can be a labour-intensive and time-consuming process (Gabriel *et al.* 2005).
- **Fish pumps:** In some fishing operations, rather than using a brailer, the fish may be sucked up using fish pumps. The fish can be removed rapidly from the purse seine to the hold (Gabriel *et al.* 2005).

The construction of purse seine nets depend on the characteristics of the oceanic areas where they will be used (e.g. thermocline depths) and the behaviour of the target species. While sinking, the net shape is affected by currents, by its construction (materials, etc.) and by the movements of the vessel (Kim *et al.* 2007). Sinking speed is a very important variable that may affect the captures in a set, although these data are seldom available. Before net encirclement is complete, there are two escape routes for fish and non-target species: dive under the net, or swim through the open section

of the net. For some species, the thermocline may act as a barrier to keep them from escaping vertically (i.e. under the net). For other species, their perception of the situation is unclear, given the dimensions of the net, and the escape options are not identified as such. For very large animals, such as whales, a third option is to simply charge the netting and break through. The pursing operation begins to close the bottom of the net. In a later stage, the escape routes are restricted, and when pursing is finished, and the purse cable has closed the bottom opening, there are no more escape routes. As the mesh is more than 10 cm stretched mesh, very small individuals can go through it, although not all species will be willing to squeeze through a tight opening (Hall and Roman 2013).

In general, for large purse seines (nets >1200m in length), the net setting and pursing process usually lasts less than 30 minutes. However, sets in adverse environmental conditions, or with malfunctions, may take much longer. After the net is closed, the volume of the net is reduced to facilitate the loading of the catch. This phase of the set may last several hours, depending on the volume of the catch, and the size of the brailer. The duration of the set is important for judging the level of stress of the individuals captured and their chances of survival if released. The geometry of the net during the set is also significant for understanding the vertical dimension of the operation and the volume enclosed, which may determine which schools and individuals are captured (Delgado de Molina *et al.* 2011; Hall and Roman 2013).

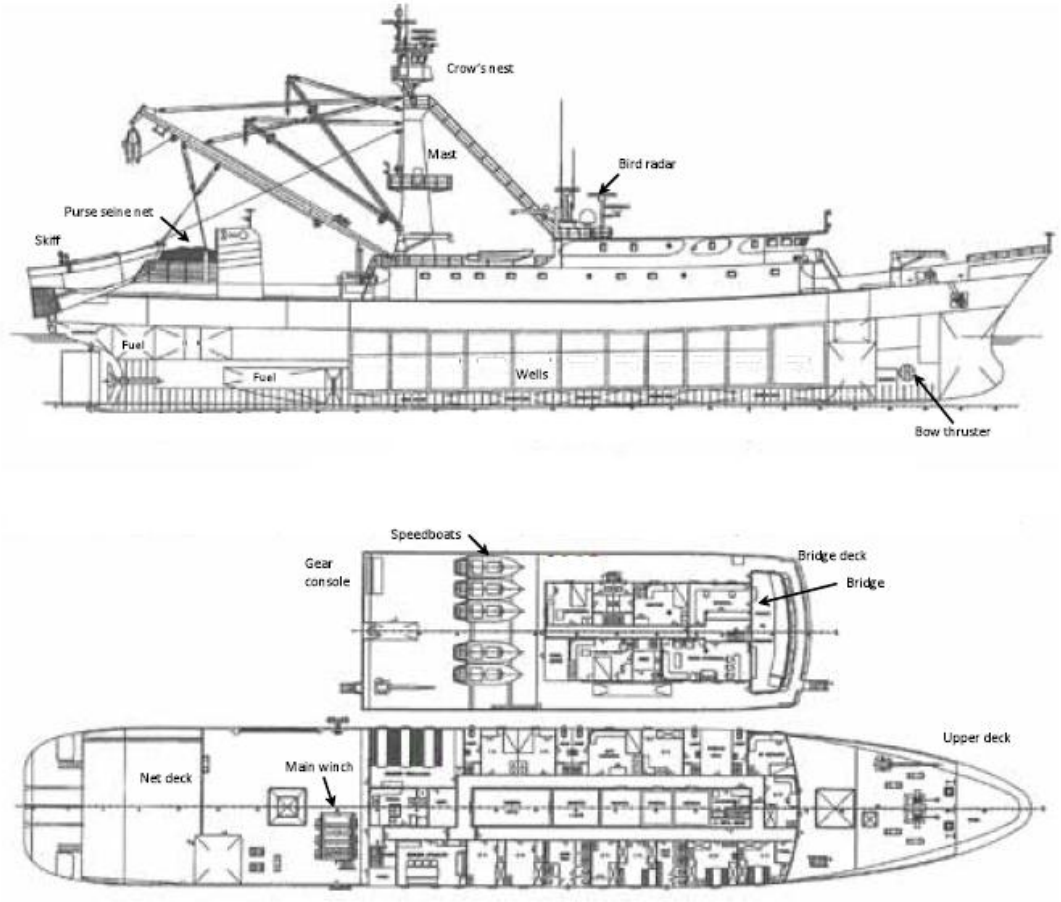
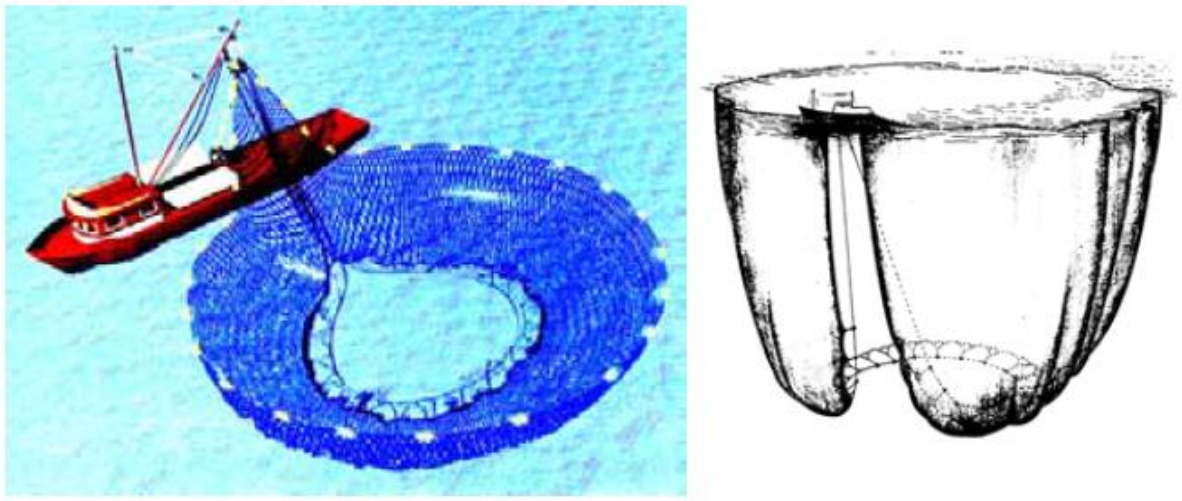
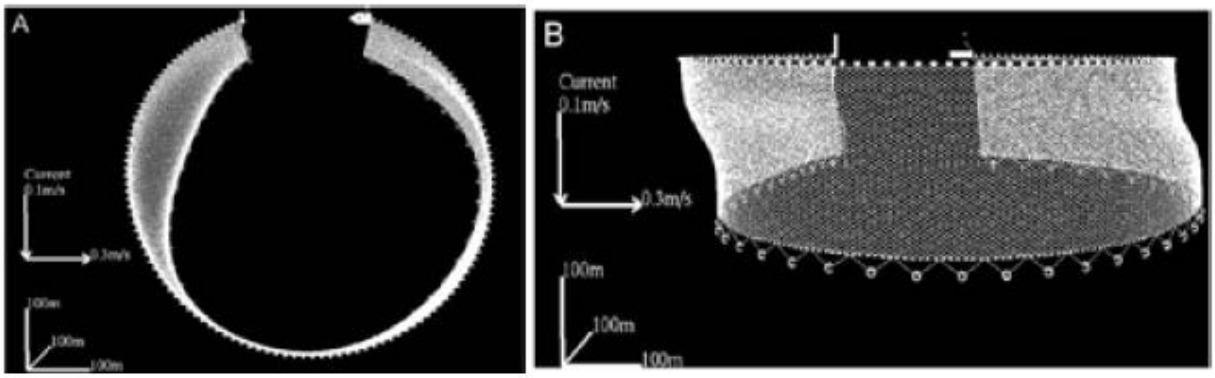


Figure 1: Diagram of a tuna purse seine vessel (from Hall and Roman 2013).



Graphic by Jim Bean for NOAA/Communications Collective

Figure 2: Diagram of the structure of most purse seines used in the tuna fisheries (from Hall and Roman 2013).



Source: Kim and Park (2009).

Figure 3: Diagram of purse seine net encirclement (from Hall and Roman 2013).

In tuna fisheries, fish arriving on the deck of the seiner either (i) go to a platform on the deck used for sorting (the hopper) and from there down to the wells; or (ii) are transferred directly through an opening on the main deck to the well deck at a lower level for sorting on a conveyor belt that carries the fish to the wells. Many larger vessels are now using this second method. Fishes that are selected to be discarded are set aside and may remain on the main deck, or on the well deck, until the crew has finished handling and storing the catch. In some vessels, another conveyor belt is used to carry the individuals to be discarded to the side of the seiner for release. In industrial tuna purse seiners, the tuna catch is kept in 20–100 tonne wells with brine freezing at –20 °C (Hall and Roman 2013).

The proportion of the global tuna catch landed by purse seiners exceeded that of the longline and pole-and-line fleets in the mid-1970s and is still increasing (see Figure 4). Globally, there are about 570 large-scale (>383 m holding capacity) purse seine vessels; 450 of these operate in the Pacific with a combined carrying capacity of 593,000 tonnes (Hall and Roman 2013). The number and holding capacity of purse seine vessels has been steadily increasing since the early 1980s.

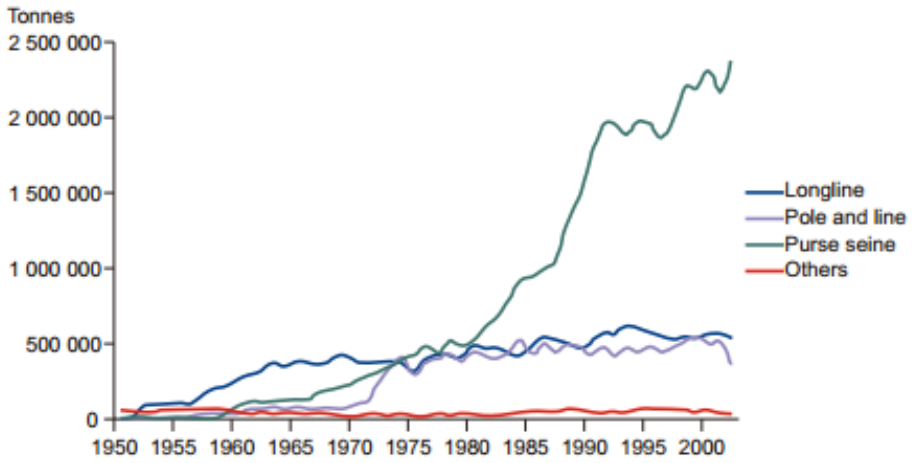


Figure 4: Trends in weight of world reported landings of principal market species of tunas by fishing gear type (from FAO 2009).

Most seiners that participate in the tuna fisheries are operated by a single boat, with or without an auxiliary skiff. The strongest part of the net, the "bunt", is where the catch is concentrated and is usually placed at one end of the purse seine. Handling of the gear may be mechanized, e.g. by a hydraulic power block or a net drum. (ICES 2009; further information is also available at www.fao.org/fishery/vesseltype/150/en) (Hall and Roman 2013).

1. The **power block** is a mechanised V-shaped pulley driven hydraulically. The power block is hung on the end of a beam (derrick) or on a crane at some height over the water surface. The narrow angle of the net creates sufficient friction in the rubber-lined 'V' sheave to apply a strong tractive effort on the netting. The net is then hauled quickly and with minimal manual effort. Power blocks are used for transporting the nets on board the vessel or back onto the wharf (Gabriel *et al.* 2005).
2. For handling and storing smaller purse seines and other fishing gear, a **net drum** is often used. The purse seine is hauled over a large roller at the stern of the vessel and wound up together with the purse line on a large drum. This drum or reel is used in purse seining for setting, rewinding and carrying the gear (Gabriel *et al.* 2005).

Most seiners carry an array of instruments to facilitate navigation and assist with detection of tuna schools. They include:

- bird radar which is used to detect seabirds frequently associated with tuna schools (Hall and Roman 2013).
- echo sounder/fish finder/sonar which provides information on the location of targets, school volume/tonnage. Models with multi-beam and split-beam transducers can provide some additional information on fish size distributions (Hall and Roman 2013).
- spotter aircraft (aeroplanes and helicopters) to assist in locating schools of tuna (Gabriel *et al.* 2005).
- satellite imagery which can assist with the detection of tuna schools that are not associated with dolphins (Gabriel *et al.* 2005).

For tuna fishing, although the purse seining operation is always basically the same, there are different ways in which tunas are detected and encircled which gives rise to the following classification of purse seine sets for tuna (Hall and Roman 2013):

- **School Sets (or Unassociated Sets):** The tuna school is detected because of its activity at or near the surface of the water. Fishers recognize and identify a variety of school sets with different, colloquial names usually based on the fish behaviour or weather/light conditions. According to IATTC database records obtained from fishers' logbooks since 1955, there are a range of terms used for different types of school sets e.g. Breezers, Jumpers, Boilers, Foamers, Black Spot, Finners, Fireballs, Shiners (Hall and Roman 2013).
- **Dolphin/Porpoise Sets:** Yellowfin tunas can be found in the Eastern Pacific Ocean (EPO) in association with dolphins of the genera *Stenella* (*S. attenuata* and *S. longirostris*) and *Delphinus* (*D. delphis*). Fishers detect a group of dolphins and give chase with several speedboats until the group is "turned" and stops. They then encircle the group of dolphins and associated yellowfin tuna (Hall and Roman 2013).
- **Sets on seamounts:** In many regions, tuna schools are found associated with seamounts (Hall and Roman 2013). As there are probable ecological differences near seamounts compared with the open ocean, it is possible that the bycatch in these sets is different, although there are limited analyses available to support or disprove this theory (Hall and Roman 2013).
- **Sets on live whales:** Sets on tuna schools associated with live whales are considered a separate type because of the behaviour of the animals that creates different conditions for the association. These sets are quite rare (Hall and Roman 2013).
- **Floating Objects Sets:** Many marine species are found on or under floating objects and the association with these objects, ranging from physical attachment to looser associations, affect their biology, ecology and biogeography. The bait species associated with floating objects attracts larger fish species. Tuna and other pelagic fish naturally congregate around floating objects in the open ocean. Setting around floating objects can be substantially more efficient than setting on unassociated schools. In the period 1987–1990 for tuna fisheries in the Eastern Pacific Ocean (EPO), the main types of objects sighted and set on were plant material, wooden artefacts, specially constructed Fish Aggregating Devices (FADs), bycatch equipment, non-wooden artefacts, dead animals and kelp (Hall and Roman 2013):
    i. **Log set:** Used to define a range of sets that not only include logs, trees and organic matter but also human-made objects found adrift (e.g. wooden objects - boxes, crates, planks, etc.; discarded fishing gear; dead animals; kelp 'patties'). The objects that attracted tunas include a wide range of shapes, sizes, colours, and materials.
    ii. **Fish Aggregating Devices (FAD) sets:** A FAD is a floating object that has been specifically constructed or modified in some way to enhance its attraction and, in particular, to improve the chances of locating it again (e.g. using radar reflectors, flags, radio buoys, self-call buoys and satellite devices). Drifting FADs can be quite sophisticated, equipped with buoys that can be located remotely and which transmit estimates of the fish biomass aggregated underneath via satellite, which makes them particularly efficient in terms of searching for tuna (Restrepo *et al.* 2014). Most FADs contain a common set of basic components: floatation elements (usually bamboo), ropes, netting material, and some weight (Hall and Roman 2013). The vast majority of the FADs in the EPO carry 10–30 m of netting underneat).
    iii. "**Payaos**" are anchored FADs. These have been used, in particular, around Papua New Guinea and the Phillipines. Payaos are deployed and maintained by fishers, or

by local or national government agencies (e.g. the state of Hawaii, USA www.hawaii.edu/HIMB/FADS/) for use by commercial and recreational fishers (Hall and Roman 2013).

There are smaller purse seine nets used for less-industrialized fishing near coastal areas, mostly targeting small tuna-like fish, such as frigate tunas, and bonitos. These operations are not well documented, and they are believed to be of minor significance compared with the operations of the major tropical tuna fleets. However, the coastal distribution of their sets may result in encounters with high densities of some vulnerable species near breeding sites and foraging grounds (Hall and Roman 2013).

In some fisheries, fishing for sardines or squid with surrounding purse seine nets may be a nocturnal activity (Gabriel *et al.* 2005; see also Case Study 1).

b. SUMMARY OF BYCATCH ISSUES IN PURSE SEINE FISHERIES

This section summarises issues relating to the incidental capture and mortality of seabirds, as identified in the review of literature on the purse seine fishing method. The issues highlighted here are covered in more detail in the 'Case Studies' provided later in this report.

Fish Aggregating Devices (FADs)

a) **Entanglement:** Some species are vulnerable to becoming entangled in the netting materials that fishers use to wrap around and under FADs. In some cases they are long and extend deep into the water column. In the EPO, most of the FAD webbing reaches 10–30 m in depth and the number of FADs deployed has been 8,000–10,000 per year in recent years (Hall and Roman 2013). There is the additional issue of lost FADs as a component of 'ghost' fishing gear causing an entanglement hazards to species away from fishing grounds (e.g. Anderson *et al.* 2009). We found no evidence of seabirds being recorded as entangled in FADs, although the potential exists for diving species such as shearwaters to becomen entangled in FADs, particularly where netting materials have used to construct a FAD.

b) **Ecological impacts of the development of the FAD fishery:** In the tropical tuna purse seine fishery, sets on floating objects have long been known to have a higher rate of bycatch than sets on free schools (e.g. Fonteneau *et al.* 2000) The fast growth in usage of artificial FADs since the mid-1990s has prompted a number of organisations to be concerned about the impact of FAD sets on non-tuna species, calling into question the sustainability of this fishing method (Restrepo *et al.* 2014).

There have been a range of developments addressing the issues with FAD fishing (i.e. management resolutions and the development of 'eco-FADs') but these are mainly of relevance to marine mammals, turtles and sharks, and not seabirds.

Purse seine bycatch summary

We found limited evidence of seabirds being recorded as bycatch in purse-seine gear and this finding has been reported by others. For example, Gilman et al. (2011) state that seabird bycatch in purse seine fisheries is "not problematic", and no avian mortality in the Soviet tuna purse-seine fishery was reported by observers (Romanov 2002). However, large numbers of flesh-footed shearwaters (*Ardenna carneipes*) have been caught in a Western Australia purse seine fishery targeting pilchards (WA Department of Fisheries, unpublished data). Flesh-footed shearwater bycatch occurs in a

particular area of the Fishery during a period of the year when fishing effort is in close proximity to breeding grounds and when birds are provisioning chicks. Clearly, in certain situations and times, seabirds will interact freely with purse-seine gear.

All fisheries where seabird interactions with purse-seine gear had been identified were considered as potential case studies for management of mitigation. These fisheries and the nature of the interactions are described in Table 1.

c. MITIGATION TECHNIQUES

Our review of the available literature on management of seabird interactions in purse seine fisheries identified a number of mitigation measures to reduce seabird bycatch in purse seine fisheries. In Western Australia (South Coast Purse Seine Managed Fishery targeting sardines and anchovies), the following mitigation measures have been identified to reduce bycatch of flesh-footed shearwaters:

- Fishing at night and spatial closures would likely eliminate seabird bycatch in the fishery. The reported flesh-footed shearwater bycatch has a spatial and temporal component in the South Coast Purse Seine Management Fishery in Western Australia (refer Case Study 2 for details).
- Close attendance of purse seine gear during setting and retrieval during daylight operations allows the implementation of mitigation measures, particularly tow-off procedures that remove folds in the nets that can entrap birds as well as water spraying. These measures have been successful in greatly reducing seabird interaction levels.
- Additional mitigation measures are being explored to sink the float-line and create a buffer between the top of the net and the water surface. The results of these trials have not been reported.

More detail on the specific aspects of the mitigation has been provided in **Case Study 1**: South Coast Purse Seine Management Fishery.

Table 1: The fisheries considered in this review as a 'case study' along with the key information sources including global bycatch mitigation experts that were contacted to source published or unpublished literature on bycatch mitigation for purse seine fisheries.

Fishery	Case Study (if applicable)	Fishery information and potential bycatch species/groups	Summary of purse seine bycatch and mitigation techniques	Key information sources
South Coast Purse Seine Management Fishery (Department of Fisheries, **Western Australia**)	Case Study 1	• Fishery mainly targets pilchards (sardines) • Main bycatch species is the flesh-footed shearwater (*Ardenna carneipes)*	• Bycatch of shearwaters has a strong seasonal and spatial component (15 March-30 April, King George Sound). • Bycatch of flesh-footed shearwaters is high during a period of the year when fishing effort occurs in close proximity to breeding grounds and birds are provisioning chicks. • Shearwater bycatch is only problematic in one sector of the Fishery, and when fishing effort is undertaken during daylight hours. • Mitigation measures include tow-off procedures that remove folds in the nets that can entrap birds, and water spraying. • Additional mitigation measures are being explored to sink the float-line and create a buffer between the top of the net and the surface. The results of these trials have not been reported.	Nic Dunlop; WA Conservation Council Western Australian Dept of Fisheries Molony *et al.* (2013)
Chub mackerel purse seine fishery in **Northern Argentina**	Case Study 2	• A range of seabird species (including white-chinned petrel, black-browed albatross, kelp gull, southern giant petrel) and the South American sea lion are attracted to fishing operations.	• The target fish, chub mackerel, is lured to the surface using cooked bait prior to fishing. This practice is likely to attract the range and number of seabirds and sea lions observed. • Although contact with fishing gear was recorded (in particular with white-chinned petrels, kelp gulls, southern giant petrels and South American sea lions) none of the seabird or marine mammal species was observed to be incidentally captured during monitored research trips.	Marco Favero, personal communication. Seco Pon *et al.* (2012)

Fishery	Case Study (if applicable)	Fishery information and potential bycatch species/groups	Summary of purse seine bycatch and mitigation techniques	Key information sources
South Australian Sardine Fishery (Primary Industries and Regions South Australia Fisheries and Aquaculture)	Not included as a case study. No significant seabird bycatch	• There are interactions with non-target species in the fishery, mostly with dolphins, seals and sharks. • Interactions with seabirds are rare, most likely because fishing activities are predominately undertaken at night.	• Bycatch mitigation has focussed marine mammal issues, with no specific mitigation considered necessary for seabirds.	Hamer et al. (2008) and other references cited in the Case Study.
Southern Bluefin Tuna Purse Seine Fishery, Port Lincoln, **South Australia** (Australian Commonwealth Government management fishery)	Not included as a case study. No significant seabird bycatch.	• No seabird species were assessed to be at high risk in a Level 2 ERA. In 2009, there were approx. 3,000 'interaction' observations of seabirds (2,784 birds) in vicinity of purse-seining vessels but no records of any seabird having contact with vessels or gear (AFMA unpublished data). In 2008, out of nearly 600 seabird 'interactions', one (a sooty shearwater *Ardenna griseus*) became snagged in a rope and was subsequently freed (AFMA unpublished data). • No interactions with seabird species were reported for the SBT Fishery in 2013 (Patterson *et al.* 2014).	• Overall, purse seine fisheries are regarded as highly selective and result in minimal interactions with non-target species. However, bycatch issues facing these fisheries are the absence of verified data on bycatch and the intentional or accidental release of targeted species for purse seine or tow nets (Baker and Finley 2013).	Baker and Finley (2013) Patterson *et al.* (2014)

Fishery	Case Study (if applicable)	Fishery information and potential bycatch species/groups	Summary of purse seine bycatch and mitigation techniques	Key information sources
Small Pelagic Fishery, **southern Australia** (Australian Commonwealth Government management fishery)	Not included as a case study. No significant bycatch issue.	• Interactions with seabirds not identified as a significant issue in the Fishery (Moore *et al.* 2011). Interactions generally low with a few isolated interactions reported in the 2005/2006 season (AFMA 2014a). • A single interaction comprising a yellow-nosed albatross was reported in 2006 by observers during purse-seine operations; the bird was released alive. No further interactions were reported during purse-seine operations during 2001-2011. (Tuck *et al.* 2013). • A risk assessment conducted for purse-seine fishing (AFMA 2010a, 2010b) did not identify any seabird species as being at high risk within the SPF (Moore *et al.* 2013).	• No recorded interactions with TEP species in either the trawl or purse-seine sector of the SPF in 2009-10 fishing season (AFMA unpublished	Moore *et al.* (2011) Moore *et al.* (2013) AFMA (2014a) AFMA (2010a) AFMA (2010b) Baker and Finley (2013) Tuck *et al.* (2013)
Alaska salmon purse seine fisheries and Alaska herring purse seine fisheries	Not included as a case study. Lack of information on bycatch and mitigation.	• Harbour seal *(Phoca vitulina richardii)* • Humpback whale *(Megaptera novaeangliae)*	• No observer programs. • Self-reported fisheries information since 1990 records harbour seal (2 animals in 1993) and humpback whale (1994) as incidental mortality in the salmon purse seine fisheries (Allen and Angliss 2014). • In 2008, a humpback whale was reported entangled in herring purse seine 'test net'. Whale believed to have been entangled from the outside of the net after the close. Whale was entangled between 20 minutes and two hours. Fishers were able to disentangle the whale using seine skiffs. The net was damaged but the whale was released (Allen *et al.* 2014). • No bycatch mitigation information for these fisheries.	Allen and Angliss (2014) Allen *et al.* (2014)

4. CASE STUDIES - KEY FISHERIES AND MITIGATION TECHNIQUES

The following case studies (fisheries) were identified that provide information on the development, application and research into the mitigation of bycatch in purse seine fisheries:

1) South Coast Purse Seine Management Fishery (Department of Fisheries, Western Australia); and
2) Chub mackerel purse seine fishery in Northern Argentina.

CASE STUDY 1: SOUTH COAST PURSE SEINE MANAGEMENT FISHERY (DEPARTMENT OF FISHERIES, WESTERN AUSTRALIA)

Description of fishery

This fishery is based on the capture of pilchards (*Sardinops sagax*) by purse seine nets in the waters between Cape Leeuwin and the Western Australia/South Australia border. The South Coast Purse Seine management plan 1994 also covers the take of yellowtail scad (*Trachurus novaezelandiae*), Australian anchovy (*Engraulis australis*), scaly mackerel (*Sardinalla lemuru*), sandy sprat (*Hyperlophus vittatus*) blue sprat (*Spratelloides robustus*) and maray (*Etrumeus teres*) (Molony *et al.* 2013).

Purse seine is the only fishing method employed within this fishery (WA Department of Fisheries, unpublished data). There are 33 active licences operating from between 12 and 17 vessels at any given time. All vessels are between 15 and 30 metres in length (WA Department of Fisheries, unpublished data).

Fishing areas

The fishery consists of five management zones. The Albany zone extends from point D'entrecasteaux to Cape Knob. The King George Sound zone is a subset of this area and the two zones are reported together (zone 1 and 2). The Bremer Bay zone (zone 3) extends from Cape Knob to longitude 120ºe. The large Esperance zone (zone 4) extends from 120ºe to the WA/SA border. An additional zone (zone 5) exists between Cape Leeuwin and Point D'entrecasteaux but has not been significantly fished to date (Molony *et al.* 2013).

Catch and effort

The commercial pilchard catch in the 2011/12 season was 2,380 t (Table 2) which is similar to catches reported in recent years (2010/11: 2,322 t; 2009/10: 2,647 t) although there has been an increasing trend in catch size since the late 1990s. The 2011/12 pilchard catch in the south coast purse seine fishery was the second highest since 1998. Less than 8 t of other pelagic species (dominated by yellowtail scad) were also landed (Molony *et al.* 2013).

Effort in the south coast purse seine fishery was within the range of recent years in 2011/12, with a total of 1,359 days of fishing (2010/11: 1,290 days; 2009/10: 1,450 days; Table 2). Compared to 2010/11 fishing season, effort increased in the Albany zones (zones 1 and 2), decreased in the Esperance zone (zone 4), and was stable in the Bremer Bay zone (zone 3) (Molony *et al.* 2013).

Most of the commercial catches were reported from the Albany zones (1,641 t). However, overall effort and catches remain below those recorded during the late 1980s and 1990s (Molony *et al.* 2013).

Table 2: Pilchard catches and TACs in tonnes (t) between 2005/06 and 2011/12 in each of the major Management Zones in the South Coast Purse Seine Fishery (Molony *et al.* 2013).

Year	Albany (Zone 1&2)	Bremer Bay (Zone 3)	Esperance (Zone 4)	Total Catch (all zones)	TAC (all zones)	Fishing effort (all zones)
2005/06	1,342t	391t	138t	1,871t	4,500t	1,380 days
2006/07	1,440t	167t	11t	1,618t	5,722t	1,206 days (161 trips)
2007/08	1,457t	192t	82t	1,735t	5,683t	1,400 days (264 trips)
2008/09	1,351t	512t	139t	2,001t	5,683t	1,316 days (233 trips)
2009/10	1,796t	422t	429t	2,647t	5,683t	1,450 days (277 trips)
2010/11	1,241t	Not reported *	Not reported *	2,322t	5,683t	1,290 days
2011/12	1,641t	Not reported *	Not reported *	2,380t	5,683t	1,359 days

* Three or less vessels operated in each of these zones in 2010/11 and 2011/12 and cannot be reported.

Nature and extent of interaction with threatened species and bycatch problem

Seabird interactions in this fishery are highest in the King George Sound area (Zone 1), where fishing effort occurs during daytime hours for reasons of fishing efficiency (Table 3). Fishing in all other areas of the fishery occurs predominantly at night and, therefore, the chance of interactions with seabirds is greatly reduced (Nic Dunlop, WA Conservation Council, pers. comm.).

In the past, Australian sea lions and bottlenose dolphins, *Tursiops* sp., have been taken in the purse seine fishery for pilchards (Shaughnessy *et al.* 2003).

Table 3: Estimated total annual catch of seabirds per unit effort (WA Department of Fisheries, unpublished data).

Season	No. of trips	Observed trips	Number entangled	Entanglement Rate (birds/ trip)	No. of mortalities	Mortality Rate (birds / trip)	per cent mortalities /entanglement
2006/ 07	161	48	512	10.66	54	1.12	10.5
2007 /08	264	64	395	6.17	54	0.84	13.6
2008/ 09	233	233	885	3.79	148	0.63	20.0
2009/ 10	277	277	245	0.88	15	0.05	6.12
2010/ 11	271	271	825	3.04	103	0.38	12.48

Mitigation techniques and efficacy of mitigation

In 2006, the Department of Fisheries working group examined the issue of seabird interactions within purse seine fishing operations and developed strategies for the mitigation of seabird bycatch. A code of practice, which is supported by industry, has been adopted by the Fishery with the aim of reducing seabird entanglements and mortalities (SeaNet 2008). Since 2006/07, the South Coast Purse Seine fishery protected species bycatch mitigation program has undertaken a range of measures to monitor and mitigate shearwater bycatch during the peak interaction period from 1 March to 30 April. These bycatch mitigation measures are reviewed annually and are continually being refined and improved. This fishery is planned to undergo Marine Stewardship Council pre-assessment in late 2014 (Molony *et al.* 2013).

In 2006, following directives from the Minister for Fisheries, the industry met to develop a strategy to manage bycatch of flesh-footed shearwaters (*Ardenna carneipes*) in the South Coast Purse Seine Fishery focused on Zone 1 (King George Sound, Albany) where most of the interactions have been occurring. From the 2006/07 season, the fishery undertook a range of measures to monitor shearwater bycatch during the peak interaction period between 1 March and 15 April and again in the 2007/08 season from March 1 to 30 April. Outside of the peak period effort occurs less during the day and more at night, noting that fishing at night decreases interactions with shearwaters.

The agreed management measures include the submission of bycatch report forms and an implementation of an observer program. Two observers were engaged to record the outcomes of fishing operations during the monitoring/mitigation period (WA Department of Fisheries 2008).

Monitoring and mitigation of seabird bycatch was undertaken for the period 2008-1012, and involved comprehensive bycatch reporting of all fishing trips by all vessels operating in the fishery. The project focused on reducing the incidental mortality of flesh-footed shearwaters in Zone 1 of the fishery where the vast majority of interactions with this species occur.

Bycatch of shearwaters averaged 2.57 birds entangled per trip over the period 2010-2012, with a mortality rate of 0.35 birds per trip. This represents a reduction over the rates observed in 2006/07 (entanglements: 10.66 birds per trip, mortality: 1.12 birds per trip), but extrapolation to total fishing effort in Zone 1 indicates total entanglements and mortalities could still be as high as 1,100 and 220 birds per season, respectively.

In 2007/08, analysis of observer data for validation purposes revealed that fishers reported a shearwater entanglement rate of 1.54/trip compared to a rate of 6.17/trip recorded by observers. For mortalities, the comparative rates were 0.29/trip for fishers and 0.84/trip for observers, allowing the calculation of an under-reporting factor of 2.89. Similar patterns of erroneous reporting have been observed in many other fisheries e.g. Phillips *et al.* (2010).

An observer program for this fishery ended in 2009 and has been replaced by bycatch reporting using bycatch record sheets of all fishing trips by all vessels in the fishery. All shearwaters killed must be recovered, labelled and retained, allowing fisher bycatch reporting to be cross-checked with the retained birds (WA Department of Fisheries, unpublished data). During 2011, the level of shearwater activity in King George Sound returned to levels that were considered to be within normal parameters (WA Department of Fisheries, unpublished data).

Mitigation measures

The special shearwater management period is concentrated between 15 March and 30 April and requires:

- the completion of bycatch record sheets for all fishing trips;
- a dawn closure;
- the presence of three crew members during daylight operations to implement mitigation measures such as tow-off procedures that remove folds in the nets that can entrap birds; water spraying; or any other potential benign mitigation measure.

In 2012, over the two-week peak seabird interaction period, additional mitigation measures were being explored by industry to sink the float-line and create a buffer between the top of the net and the surface. This is being done in conjunction with Seanet/WA Fishing Industry Council and the Conservation Council of WA. The outcome of this work has not been reported upon.

Current management requirements

The South Coast Purse Seine Managed Fishery, Industry Code of Practice for Responsible Fishing manual has been designed to assist fishers recognise and respond effectively to interactions with wildlife, as well as minimise impacts on the immediate environment. The manual is provided to all fishers so that it can be readily accessible for skippers or crew, and provides information including:

- Protocols for net setting;
- Dealing with entanglements;
- Guides for species identification; and,
- How to report seabird interactions (SeaNet 2008).

This fishery is primarily managed through output controls in the form of individual transferable quota (ITQ) units. Four (Zones 1 – 4) of the five zones in the fishery have been allocated a set amount of ITQ units which are determined by dividing the total allowable catch for that zone by the total number of units allocated to that zone. The TAC has been relatively stable over the past 10 years and will be reviewed on an 'as needs' basis but is primarily dependant on the status of fish stocks. The total number of units allocated across each of the four zones in the fishery amount to 890 and remained unchanged from the previous season (WA Department of Fisheries 2012).

Key points:

- Bycatch of flesh-footed shearwaters is high during a period of the year when fishing effort occurs in close proximity to breeding grounds and birds are provisioning chicks.
- Shearwater bycatch is only problematic in one sector of the fishery, and when fishing effort is undertaken during daylight hours.
- Reported bycatch has a spatial and temporal component. Fishing at night and spatial closures in Zone 1 (King George Sound, Albany) would likely eliminate seabird bycatch in the fishery.
- Close attendance of purse seine gear during setting and retrieval during daylight operations allow the implementation of mitigation measures, particularly tow-off procedures that remove folds in the nets that can entrap birds as well as water spraying. These measures have been successful in greatly reducing interaction levels.
- Additional mitigation measures are being explored to sink the float-line and create a buffer between the top of the net and the surface. The results of these trials have not been reported.

CASE STUDY 2: CHUB MACKEREL PURSE SEINE FISHERY IN NORTHERN ARGENTINA

Description of fishery

In northern Argentina, the chub mackerel *Scomber japonicas* has being targeted by the semi-industrial coastal purse seine fleet for the last few decades. The fishery runs from late spring (i.e. mid October) to early summer (i.e. mid-January) (Seco Pon *et al.* 2012).

Seco Pon *et al.* (2012) conducted a study to record potential bycatch species interactions on fishing vessels operating off Mar del Plata Harbour and Mar Chiquita in the southeast Buenos Aires Province, Argentina. The Mar del Plata Harbour is the most important commercial harbour in the country, comprising 70% of the coastal fleet (~ 190 vessels) and contributing c. 80% of the national coastal fishery catch (Lasta *et al.* 2001 in Seco Pon *et al.* 2012). Over 60% of the coastal fleet based at Mar del Plata Harbour consists of small-scale vessels locally known as "rada o ría". Technically, these vessels are included within the semi-industrial national fleet (Santos 2010 in Seco Pon *et al.* 2012). These fishing vessels range from 9-18 m in length and 3-4 m in width and have 6-12 ton carrying capacities. Vessels lack refrigeration and perform daily trips operating 16-18 km offshore within the 50 m isobath (e.g. Lasta *et al.* 2001 in Seco Pon *et al.* 2012). The majority of the vessels are equipped with VHF radio and echo-sounders. Approximately 35 coastal vessels seine for chub mackerel year-round. The catch is usually sorted on deck and preserved within plastic cubes (ca. 0.05 m^3). Non-target fish species comprise c. 30% of the catch, and are dominated by the rough scad *Trachurus lathami* (Garciarena *et al.* 2002, 2008 in Seco Pon *et al.* 2012). The total annual catch of chub mackerel landed at Mar del Plata Harbour by this fishery is about 18,000 tons (average for the period 2000-2009, Ministerio de Agricultura, Ganadería y Pesca (MAGYP) 2011 in Seco Pon *et al.* 2012).

The chub mackerel is caught with purse seine nets locally known as *lampara nets* (Figure 5). This net has netting walls framed with a float-line supported by numerous floats. It does not have a lead-line at the bottom but has a central bunt in the form of a spoon and two lateral wings (Nédelec and Prado 1990). The chub mackerel is lured toward the sea surface using bait (mainly heads of anchoita (*Odontesthes* spp.), mackerel discards and rough scad) which has been cooked onboard a few hours before fishing (Izzo and Boccanfuso 1993 in Seco Pon *et al.* 2012). The use of bait during the fishing operation is considered a standard and effective practice among local fishermen (Izzo and Boccanfuso 1993 in Seco Pon *et al.* 2012). Once the mackerel has been lured toward the surface, the purse seine from the bow is lowered to encircle the fish. The seine is then hauled onto the weather side of the vessels (Izzo and Boccanfuso 1993 in Seco Pon *et al.* 2012). The fishing operation is conducted during daylight and, in general, vessels return to port when the catch is completed.

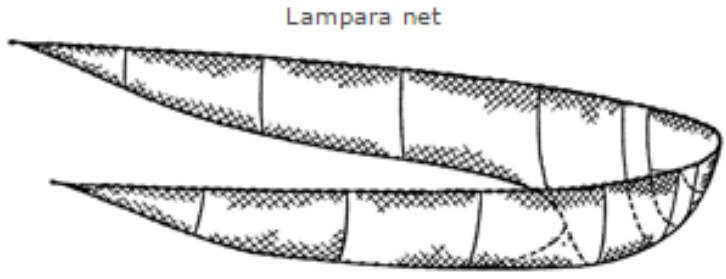


Figure 5: Diagram of a lampara net (from FAO 2014 website http://www.fao.org/fishery/geartype/201/en).

Nature and extent of the bycatch species interaction and bycatch problem

Although purse seine fishing gear was introduced in Argentina in 1940, there are very limited data available regarding the potential impact of purse seining on marine top predators in these fisheries (Seco Pon *et al.* 2012). Purse seines are presently considered to have a low impact on ecosystems although it is unclear if this conclusion is simply a reflection of the lack of data (Fuller *et al.* 2008).

Seco Pon *et al.* (2012) undertook the first assessment of seabird and mammal interactions in the chub mackerel semi-industrial coastal purse seine fishery in northern Argentina from late spring 2007 to early summer 2008. The study area included the fishery area off Mar del Plata where the waters are widely utilised throughout the year by a number of globally threatened seabird species. The distribution range of the Franciscana dolphin *Pontoporia blainvillei* in Argentina is restricted to coastal waters within the 30-m isobath overlapping with the one of the fisheries areas (Crespo *et al.* 2010). In addition, since the 1960s, a rookery of non-breeding male South American sea lions *Otaria flavescens* has been located within Mar del Plata Harbour with a current population size estimated at 500-600 individuals (Bastida *et al.* 2007 in Seco Pon *et al.* 2012). There have been few attempts to estimate the magnitude of the bycatch problem in coastal fisheries. Seco Pon *et al.* (2012) aimed to (1) examine the abundance and composition of seabirds and marine mammals attending small-scale purse seine vessels targeting chub mackerel, and (2) estimate the intensity of interactions with fishing gear and associated mortality.

Sixteen marine top predator species attended vessels, and the most abundant seabirds (percent of overall individuals and percent of occurrence) were the kelp gull *Larus dominicanus* (25% and 40% respectively), and white-chinned petrel *Procellaria aequinoctialis* (24% and 47% respectively). Other attending bird species were the black-browed albatross *Thalassarche melanophrys* (18.5% and 12% respectively) and South American tern *Sterna hirundinacea* (30% and 22% respectively). The most abundant marine mammal species was the South American sea lion *Otaria flavescens* (2% and 8% respectively). Analysis of environmental and operational variability affecting the abundance of the four main seabird species indicated a clear spatial variability in the numbers of seabirds attending coastal purse seiners. Other factors included fishing operation, time of day, seasonality, and wind intensity and wind direction (Seco Pon *et al.* 2012).

Overall, a total of 42 marine top predator (i.e. seabird and marine mammal) interactions were observed during 82 fishing operations undertaken over 25 days at sea (Table 4). The vast majority (>85%) of the interactions were recorded during hauling operations. Of the 42 observed interactions with the fishing gear, around 70% involved white-chinned petrels, 20% South American sea lions, and 5% kelp gulls and southern giant petrels (Table 4). The majority of these interactions were light contacts (birds on the water) or sea lions near gear (without contact) chiefly with the float-line and with the fishing net (70% and 38% in white-chinned petrels and South American sea lions respectively) during hauling. None of the seabird or marine mammal species was observed to be incidentally captured during any of the monitored trips (Table 4) (Seco Pon *et al.* 2012).

The chub mackerel purse seiners strongly attract marine top predators in the near shore waters of southeast Buenos Aires Province. Although bycatch of seabirds and marine mammals does not seem to be a problem in this purse seine fishery, it remains unclear how the increasing effort in the chub mackerel fishery operating off Mar del Plata will affect top predators.

Table 4: For the main interacting species, the summary of contacts (%) between several marine top predator species and coastal chub mackerel purse seiners monitored off the Mar del Plata Harbor during shooting and hauling operations. KPG: Kelp Gull; WCP: White-chinned Petrel; BBA: Black-browed Albatross; SGP: Southern Giant Petrel; SSL: South American sea lion. From Seco Pon *et al.* (2012).

	Interaction species				
	KPG	WCP	BBA	SGP	SSL
Contact code					
1. Bird on water, light contact with gear; sea lion near gear but no contact	0	100[a]	100	0	0
2.Bird on water, heavy contact with gear; sea lion light contact with gear	100	0	0	100	62.5[b]
3. Bird flying, light contact; sea lion climbs on net	0	0	0	0	0
4. Bird flying, heavy contact with gear; sea lion caught on net	0	0	0	0	0
5. Bird caught in net	0	0	0	0	
6. Bird snagged on net while attemping to feed	0	0	0	0	0
7. Sea lion snagged on net while attemping to feed	0	0	0	0	37.5
Contact point					
1. Buoy	0	0	0	0	62.5[b]
2. Floatline	0	0	0	0	0
3. Net	100	100[a]	100	100	37.5
4. Leadline	0	0	0	0	0
5. Vessel	0	0	0	0	0
6. Other	0	0	0	0	0
Fate					
1. Individual with no apparent injury	100	100[a]	100	100	62.5[b]
2. Individual with possible minor injury	0	0	0	0	0
3. Individual with possible major injury	0	0	0	0	37.5
4. Individual captured dead	0	0	0	0	0
5. Unknown	0	0	0	0	0
Total number of observations	**2**	**29**	**1**	**2**	**8**

[a] Two White-chinned petrels lightly conctacted the net with no apparent injury during shooting operations.
[b] Four South American sea lions climbed on the net with no apparent injury during shooting operations.

Mitigation techniques and efficacy of mitigation

In the Seco Pon *et al.* (2012) study, few sea lions were snagged on the purse seine net while attempting to feed and all caught individuals were observed to free themselves from the gear. No mitigation devices (e.g. tori-lines) were or are being used by the chub mackerel purse seine fleet to avoid or minimize interactions with marine top predators (Seco Pon *et al.* 2012).

Key points:

- Chub mackerel are caught using lampara nets that do not have a lead-line at the bottom. However, it is assumed that any seabird interaction in this fishery would be the same as if a standard purse seine net was deployed.
- Cooked bait is used to lure chub mackerel to the surface before fishing.
- A number of seabird species (including globally threatened species) and the South American sea lion are attracted to the vessels during the fishing operation although this is likely due to the use of bait.
- Although contact with fishing gear was recorded, none of the seabird or marine mammal species was observed to be incidentally captured during any of the monitored trips.

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