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Study of Ghost Fishing in the NSW Rock Lobster Fishery

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Executive Summary

This project concerns an assessment of the significance ghost fishing in the NSW Rock Lobster Fishery and potential modifications to fishing gears and practices that could minimise trap loss and consequent ghost fishing of the target species, Eastern Rock Lobster, *Sagmariasus verreauxi*. The significance of ghost fishing in the deep-water component of this fishery was established by experiments that simulated ghost fishing over the life of traps set at 2 locations. Two approaches to minimise the potential for ghost fishing were examined in this project. The potential for trap doors to function as sacrificial panels that would facilitate the escape of lobsters from lost traps was examined experimentally. Longevity of wire mesh in the doors of traps was manipulated by excluding or varying the size of the sacrificial anode that provides cathodic protection to the wire mesh in the door. In contrast, the second approach to minimising ghost fishing considered here involved the use of technology that would minimise loss of traps in the first place, thereby minimising ghost fishing. We assessed the practical application of an acoustic release system that could provide at-call access to the submerged head-gear (floats and rope) of traps. Submerged head-gear is not exposed to the risk of being cut-off by shipping, theft or vandalism and consequent loss of access to the trap is thereby minimised. The ambition was to provide proof of concept and proof of effective application of this technology in the deep-water fishery for lobsters off NSW and this was achieved. The subsequent purchase and implementation of this system by several commercial lobster fishers in NSW represented the first routine use, anywhere in the world, of acoustic release technology to control access to commercial fishing gear.

Background

Ghost fishing occurs when fishing gear is lost,abandoned or discarded but continues to capture and/or kill organisms. Ghost fishing has been shown internationally to be significant in several crustacean fisheries. It therefore needs to be quantified because it represents a component of fishing mortality that, if not accounted for, will bias any estimates of fishing mortality that are used in fisheries assessment models to manage stocks. Moreover, any losses from ghost fishing are undesirable both from economic and conservation points of view.

The NSW Rock Lobster Fishery targets the Eastern Rock Lobster, *Sagmariasus verreaxi,* along the entire coast of NSW in depths out to the edge of continental shelf. The deep-water components of this fishery on the mid and outer continental shelf involve the use of large traps and long soak-times (weeks or months). Between 2004 and 2006 NSW DPI completed a small pilot study of ghost fishing in mid-shelf waters off Jervis Bay. Traps continued to accumulate lobsters over many months and it was concluded that ghost fishing warranted further evaluation.

Aims/objectives

Assess the mortality of lobsters due to ghost fishing of traps in the deep-water component of the fishery.

Design and test modifications to traps that facilitate the escape of lobsters from lost traps prior to mortality

Develop and test alternative methods for the setting of traps and deployment of head-gear to reduce mortalities of lobsters resulting from ghost fishing and theft

Methodology

The significance of ghost fishing in the deep-water component of this fishery was established using experiments that simulated ghost fishing over the life of traps set at 2 locations in mid-shelf depths (off Jervis Bay and Seal Rocks). Baited traps were initially set and then lifted and reset periodically for the life of the traps (approx. 14 months). Traps were not rebaited after the initial set. On each lift, new entrants to the traps were tagged so they could be individually identified and this facilitated identification of new entrants, residents and absentees after each soak. The experiments concluded when the replicate traps broke down allowing escape of lobsters or the traps were obviously close to breakdown. Lobsters resident in these traps provided the basis for assessing the relative condition of lobsters that had been resident for varying periods of time.

Because the wire mesh in the removable front panel (the door) of deep-water lobster traps is electrically isolated from the wire mesh in the remainder of the trap, this front panel can potentially be used as a sacrificial panel that corrodes before the wire in the remainder of the trap does and allows the escape of entrapped lobsters. Three alternative levels of galvanic (cathodic) protection (single 20 cm sacrificial anode, a single 10 cm anode and no anode) were assessed experimentally. To assess whether breakdown times for these treatments were consistent among locations, the experiment was done at 3 locations on the NSW coast (Jervis Bay, Terrigal and Port Macquarie). The influence of 2 factors that may potentially influence breakdown time, (i) water temperature and (ii) abrasion of wire mesh by lobsters and hermit crabs, were also evaluated.

Following purchase of the ARC-1XDf acoustic release system from Desert Star Systems (USA), initial familiarisation and testing of the equipment was done in a shallow pool. A system to rig the acoustic release on the side of a plastic mesh bag containing the head-gear of a trap was designed and tested. Testing the performance and reliability of the acoustic release system then progressed to testing aboard commercial lobster vessels with repeated deployments and retrievals in depths ranging from 15 – 260 m. Performance of the system was experimentally assessed during extended soaks in shallow water where biofouling was a potential issue. A single baited trap and release unit was deployed in 102 m of water off Sydney and completed 2 consecutive soaks. These trials were the necessary prelude to the major commercial fishing experiment to compare the relative performance of 6 traps with submerged head-gear controlled by acoustic release and 6 traps with submerged head-gear controlled by Galvanic Time Releases (Galvanic Time Releases). Traps were set and lifted periodically over the following 6 months. Loss of traps, relative catches of lobsters and problems associated with each method of deployment could then be determined. The first attempt at this experiment failed due to the implosion of faulty or over-rated depth floats. The experiment was repeated successfully using depth floats rated to a greater pressure

Results and conclusions

Rock lobster traps fished to simulate ghost fishing in mid-shelf depths off the coast of NSW at both Jervis Bay and Seal Rocks continued to catch and accumulate lobsters until their structural integrity was compromised after 14 months. The condition of lobsters, based on both weight at length and a qualitative index of vigour, deteriorated over time at both Jervis Bay and Seal Rocks. Weight at length and indices of vigour decreased significantly for lobsters resident in traps for periods greater than 9 months. As a proportion of the number of lobsters that entered the traps during the simulated ghost fishing, the vast majority were still resident in traps prior to trap breakdown.

Given the compromised condition of long-term residents, it is unclear what subsequent mortality these lobsters would experience following escape after breakdown of the trap. Despite uncertainty about the actual mortality resulting from lost traps and ghost fishing, it is clearly desirable to minimise the potential mortality.

Sacrificial panels unprotected from corrosion by sacrificial anodes broke down more quickly than those with 10 cm aluminium anodes which, in turn, broke down more quickly than those with 20 cm aluminium anodes. The breakdown time for sacrificial panels unprotected by anodes and those with a 10 cm anode attached varied substantially among the trials done at 3 locations (Jervis Bay, Terrigal and Port Macquarie). The staples that secured the panel wire to the door frame and the section of wire underneath the staples were the first components of the sacrificial panel to corrode and fail. Catch rates of lobsters (per trap-lift) did not differ for the 3 designs of sacrificial panel. Lobsters escaped from traps following breakdown of the sacrificial panels. There was no relationship between mean water temperature and the breakdown time of sacrificial panels for the 3 locations. Traps at the location at which sacrificial panels had the greatest longevity (Terrigal) caught significantly lesser quantities of lobsters and Hermit Crabs.

Whilst the breakdown of sacrificial panels did facilitate the escape of resident lobsters, the substantial variation in the speed of corrosion and consequent breakdown time of sacrificial panels among locations severely limits the potential for implementing a standard design of sacrificial panel across the fishery.

Moreover, further investigation and understanding of factors affecting corrosion and breakdown time and associated spatial and temporal variation is unlikely to alter this conclusion.

Experimental testing of the performance of the ARC-1XDf acoustic release system provided proof of concept and application with respect its use in providing at-call access to submerged head-gear of deep-water lobster traps used in the NSW fishery. Based on the 6-month commercial fishing trial done in mid-shelf depths off Sydney, use of the acoustic release system (incorporating a backup GTR) resulted in no loss of traps, a significantly better outcome compared to traps set using only a GTR. As a consequence, catch of lobsters over the course of the experiment was greater for the traps with head-gear controlled by acoustic releases. The use of a backup GTR in conjunction with the acoustic release enabled recovery of traps and acoustic release units in several instances when the acoustic release failed. Routine use of a backup GTR is therefore strongly recommended

Failures in 2 of the acoustic releases resulted from faults in the internal electronics of the units. This indicated the need for more stringent quality assurance and quality control procedures by the manufacturer prior to shipping.

There were several instances during testing when the acoustic release functioned correctly but the floats and rope did not immediately ascend to the surface. These incidents indicated the need for further refinement of the components of the system other than the release unit itself (design and dimensions of the release bag, rigging of the release unit on the bag, the release cord and guides for the release cord). Fishers that have subsequently purchased the ARC1-XDf acoustic release system have made further refinements as suggested and have experienced fewer instances of delayed release of floats.

Thorough cleaning of the acoustic release, release bag and rigging components following each lift of gear is also necessary to minimise the chance of subsequent release failures. This was evidenced by the trial of the system in shallow water during which biofouling accumulated quickly and the single incident during the 6-month commercial fishing trial when the release lever of one of the units was prevented from opening due to blockage by a tubeworm.

Implications and recommendations for stakeholders

Two of the fishing business that assisted with this project, having observed the system in use on their vessels, immediately purchased the ARC-1XDf system for installation on their vessels. It was their commitment to purchase of the system that prompted a subsequent successful application to FRDC for a an industry extension project: "*Industry-extension of acoustic release technology for at-call access to submerged head-gear in the NSW rock lobster fishery"* (FRDC project no. 2012/504). Objectives of this project included installation of the ARC1-XDf acoustic release system and integration with on-board electronics on several vessels operating in the NSW lobster fishery and provision of initial training and support for the effective use of the system. The acoustic release system has since been successfully adopted by several fishing business operating in the NSW lobster fishery.

Attributes of a fishing business that maximise the potential cost-benefit of the acoustic release system include: (i) a large shareholding and therefore large annual quota; (ii) high catch rates of lobsters per trap-lift during peak season such that an acoustic release costing approximately $2,000 is protecting the contents of a trap valued in the thousands of dollars; (iii) frequent losses of head-gear due to cut-offs by shipping, theft or vandalism; (iv) high likelihood of entanglement of whales during their seasonal migration such that the increased mitigation of risk offered by acoustic releases compared to GTRs is warranted; and (iv) a desire to accrue health, safety and lifestyle benefits that result from head-gear being safely submerged until weather and sea conditions are suitable and other commitments allow time at sea to lift traps.

Keywords

ghost fishing, Eastern Rock Lobster, sacrificial panels, acoustic releases

Introduction

Ghost fishing occurs when fishing gear is lost or abandoned but continues to kill targeted and non-targeted organisms (e.g. Macfadyen et al 2009, Arthur et al 2014). The same piece of fishing gear may continue to ghost fish for several years which results in additional fishing mortality to that attributed to the catch. Ghost fishing has been shown internationally to be significant in fisheries that use a variety of gears (Breen 1990, Matsuoka et al 2005, Lively and Good 2019) including trap fisheries for crustaceans (eg. Smolowitz 1978, Breen 1987, Godoy et al 2003, Arthur et al 2014). The significance of mortality due to ghost fishing of traps in fisheries targeting spiny lobster species varies from relatively minor (Parrish and Kazama 1992) to substantial (Butler and Mathews 2015). The significance of ghost fishing therefore needs to be examined for individual fisheries. If the ghost fishing component of fishing mortality is ignored, estimates of fishing mortality that are used in dynamic models to assess fisheries status and the impact of alternative management scenarios will be biased. Further, any losses from ghost fishing are undesirable both from economic and conservation points of view.

This project was specifically concerned with the environmental sustainability of fishing gear, a priority area identified by FRDC for research funding. Whilst ghost fishing has been recognised internationally for many years, it has received relatively scant attention in Australian fisheries (but see Campell and Sumpton 2009), presumably because it has not been viewed as a potential risk However, this view is now changing as industry and fisheries management agencies attempt to comply with the Commonwealth Government's Environment Protection and Biodiversity Conservation Act (EP&BC Act) 1999, individual state legislation and harvest strategy policies. If ghost fishing is occurring, then ways to alleviate the impact need to be found. For example, in some trap fisheries overseas, sacrificial components that biodegrade or galvanically corrode are used or have been recommended for use in traps and pots. If the fishing gear is lost, the sacrificial component degrades with time so that captured animals can escape from the gear (eg. Smolowitz 1978, Blott 1978, Scarsbook et al 1988, Matsuoka et al 2005, Winger et al 2015).

The NSW Rock Lobster Fishery was valued at $AUS 4-5 m per annum in the early 2000s and has since increased in value to $AUS 13.8 m in 2018-19 (NSW Government 2020). It has greater significance in NSW than this modest contribution to national production would suggest (Montgomery and Liggins 2013, Liggins 2018). The fishery targets what is locally considered to be a 'boutique' seafood and so this species brings high prices on local markets. The species, *Sagmariasus verreauxi*, is only caught in commercial quantities in waters off NSW. The NSW Rock Lobster Fishery extends along the entire coast of NSW and out to the edge of the Continental Shelf. The fishery targets Eastern Rock Lobster in inshore (<10m & 10-30m), mid-shelf (30-150m) and outer-shelf (150-200+ m) waters. The fishery is managed by a suite of input and output controls including an annual Total Allowable Commercial Catch (TACC) and individual catch quotas. In 2006-07 the fishery landed 109 t of Eastern Rock Lobster, 98% of the TACC of 112 t) from 134,460 trap lifts. The fishery has since undergone dramatic recovery (Montgomery and Liggins 2013, Liggins 2018) with landings of 169 t against a TACC of 170 t during 2018-19. The fishery on the mid-shelf and outer-shelf grounds is unlike that of other rock lobster fisheries in Australia. Fishers generally use timber framed, rectangular traps (around 2m x 1.5m x 1m) covered with 50 cm wire mesh, and use a variety of fresh and preserved baits. Soak-time for these traps is generally 2-6 weeks but current strength and weather conditions can prolong soak-time to several months. When conditions keep the head-gear submerged, so that traps are inaccessible to the fisher, the fisher considers that the trap is still viable up until the end of the fishing season. On the south coast of NSW, the mid-shelf and outer-shelf fisheries operate between October and March. On the north coast, the mid-shelf fishery is concentrated during July-November and the outer-shelf fishery during February-July. Thus, the duration of fishing season is approximately 6 months, sometimes extending to 8 months, in these mid- and outer-shelf components of the fishery.

In December 2000, the NSW government changed the way fisheries in NSW are managed so as to place increased emphasis upon ensuring that fishing activities are environmentally sustainable. The changes required the development of fisheries management strategies (FMSs) for each designated fishery. The changes also required an environmental assessment of the likely impacts of the operations described in the FMSs. The FMS for the Rock Lobster Fishery was assessed under the NSW Government's Environmental Planning and Assessment Act 1979, the Fisheries Management Act 1994 and the Commonwealth Government's EPBC Act. An outcome from this assessment process was concern about the potential for ghost fishing by large rectangular traps set on mid-shelf and deep-water grounds. Traps set on mid-shelf and deeper grounds are the most susceptible to trap loss and anecdotal reports from commercial rock lobster fishers suggested that up to 35% of these traps may be lost by some fishers in some years. Estimates provided by fishers during the mid-2000s suggested 15-20% of traps are lost annually. Anecdotal information from commercial fishers and results from a preliminary study suggest that the traps breakdown due to corrosion of the wire after about a year. Some fishers also maintain that traps degrade more quickly on the south coast than further north.

Between 2004 and 2006 NSW DPI completed a small pilot study in waters off Jervis Bay to determine whether ghost fishing occurred in the NSW rock lobster fishery. The conclusion from this preliminary research was that ghost fishing may be responsible for a loss of around 12% by weight of the commercial catch from the lobster population. Therefore, ghost fishing appeared significant. Further investigations of ghost fishing and time taken for traps to break down and allow escape of contained lobsters were required across a broader spatial scale. In particular, investigations were required on the north coast of NSW, where the presence of larger lobsters and higher water temperatures would likely result in greater metabolic rates, nutritional requirements and different behaviour of lobsters.

Discussions with commercial fishers suggested that ghost fishing may have been a relatively new phenomenon in the fishery. Since the early 2000s, fishers had been using a new product manufactured by BHP, commonly called "blue wire", to cover their traps. In contrast to the wire used previously, this wire apparently endured for a longer period. It was therefore important to assess the durability of lobster traps, and further investigate the capacity for lost traps to ghost fish. The inclusion of sacrificial panels in traps that corrode and break down to allow the escape of lobsters after an appropriate period of time represents one potential option for reducing mortality from ghost fishing.

An alternative approach involves reducing the initial loss of traps. Trap loss, resulting from lost head-gear, occurs in the NSW lobster fishery in several ways. Head-gear may be cut off by commercial shipping on grounds close to major ports (Sydney, Newcastle, Wollongong) and by commercial fishing vessels on grounds adjacent to major fishing ports. Interference with traps, vandalism and the theft of lobsters represents an additional unaccounted fishing mortality in the NSW fishery. To reduce the loss of head-gear, traps and lobsters, several fishers operating in the deep-water component of the NSW lobster fishery have, since the mid 1990s, been "sinking" their head-gear using galvanic time releases (GTRs). A GTR is used to contain the head-gear (rope & floats) within a plastic mesh bag that is suspended above a trap in mid-water between the trap and the surface. The GTR (comprising a central anode & 2 cathodes) electrochemically corrodes and eventually releases the head-gear to the surface, current permitting. Various models of GTR provide for different release times and modifications are made by fishers to extend the release time to several weeks. There is, however, an inherent variability in release time among individual GTRs and additional variability due to changes in water temperature, tensile load on the GTR and several other variables. This unpredictability results in trap floats being released to the surface earlier than expected when water temperature is warmer, later when water temperature is colder and there is variation of +/- several days in the release time of head-gear on traps set on the same ground on the same day. This lack of predictability results in inefficiencies for the fisher who is attempting to limit the duration of time that floats are on the surface and exposed to being cut-off or illegally lifted.

Acoustic releases have been used in a variety of oceanographic applications but have not, in the past, been cost-effective for fishing applications. These release devices could potentially be used to replace the GTR and provide an "at call" facility for lobster fishers to release head-gear on their traps to the surface when sent an acoustic signal from a transponder on their vessel. An appraisal of the cost-effectiveness of such devices in the NSW deep-water lobster fishery was therefore warranted due to: (i) decreasing cost of this technology and (ii) the high value of catches of lobsters from individual traps in this fishery.

Objectives

1. Assess the mortality of lobsters due to ghost fishing of traps in the deep-water component of the fishery
2. Design and test modifications to traps that facilitate the escape of lobsters from lost traps prior to mortality
3. Develop and test alternative methods for the setting of traps and deployment of head-gear to reduce mortalities of lobsters resulting from ghost fishing and theft

General methods

This project comprised 3 separate experimental components, each related to a particular project objective:

1. An experiment to simulate and assess ghost fishing

This experiment related to Objective 1 of the project: "Assess the mortality of lobsters due to ghost fishing of traps in the deep-water component of the fishery."

An experiment to simulate trap loss and assess ghost fishing was done in the deep-water component of the fishery off the north coast of NSW. This was designed to provide comparable results to those gained from a preliminary experiment that assessed ghost fishing of lobster traps in mid-shelf waters off the south coast of NSW. Both experiments involved an initial baited soak of replicate traps followed by a phase of simulated ghost-fishing during which traps were periodically lifted and reset without re-baiting. On each lift, new entrants to the traps were tagged and lobsters resident from previous lifts were identified from their existing tags. Thus, comparative rates of ingress and egress were documented over the duration of the experiment. The condition of lobsters (based on the relationship between length and weight) was also assessed at the end of the experiment.

Results from both ghost fishing experiments, completed in mid-shelf depths on both the north and south coasts of NSW, are considered here. Experimental design facilitated tests of hypotheses concerning: (i) the accumulation of lobsters in traps due to ghost fishing; (ii) deterioration in the condition (weight at length) of trapped lobsters over time; and (iii) the generality of such results for the deep water fishery in NSW (based on 2 replicate experiments).

2. Experiments to assess the utility of sacrificial panels

This experiment related to Objective 3 of the project: "Design and test modifications to traps that facilitate the escape of lobsters from lost traps prior to mortality."

This experiment was based on the idea that the door of a lobster trap could be used as a sacrificial panel such that it would corrode and break down and allow escape of lobsters after an appropriate period of time (e.g. 6 months). The ideal breakdown time would represent a trade-off between competing objectives: (i) the early release of lobsters from lost traps and (ii) maintaining trap-door and therefore trap integrity for a period equivalent to the duration of the deep-water fishing season. The experimental design involved fishing in mid-shelf depths at each of 3 sites off the NSW coast and using sacrificial panels (trap doors) with 3 different levels of galvanic protection from corrosion (20 cm anode, 10 cm anode, no anode).

This design facilitated tests of hypotheses concerning the breakdown time of doors with alternative sized anodes and differences in breakdown times among sites.

3. Experimental trials of the utility of acoustic release devices

This experiment related to Objective 2 of the project: "Develop and test alternative methods for the setting of traps and deployment of head-gear to reduce mortalities of lobsters resulting from ghost fishing and theft."

Following a review of available acoustic release devices an acoustic release system was purchased. A means of attaching the release units to bags containing the head-gear (to be submerged) was engineered and tested in preliminary trials. An experimental trial of the performance of the acoustic release system was done in mid-shelf waters off Sydney. The experimental treatment used the acoustic release system to provide "at-call" access to submerged head-gear. The ease and success in recovering gear and the resulting catches of lobsters were compared with control traps that used the pre-existing technology of galvanic time releases (GTRs) to release head-gear to the surface following galvanic corrosion of the device. The first attempt at this experiment failed due to the implosion of faulty depth-floats that were a component of both the acoustic release and GTR based treatments. The experiment was therefore repeated, using depth-floats with a greater pressure rating.

The design of this experiment facilitated tests of hypotheses concerning comparative rates of trap loss and therefore also loss of lobsters and the potential for mortality due to ghost fishing.

Simulation and assessment of ghost fishing

Introduction

Data and analyses presented here derive from experiments that simulated ghost fishing on mid-shelf fishing grounds off Jervis Bay (December 2004 - February 2006) and Seal Rocks (November 2009 – January 2011).

Designs of the 2 experiments were similar and facilitated tests of the following hypotheses: (i) un-baited traps containing lobsters in mid-shelf depths off the coast of NSW continue to catch and accumulate lobsters (ghost fishing) over time; (ii) the condition of lobsters (weight at length) resident in traps decreases over time; and (iii) the rate of accumulation of lobsters in ghost fishing traps and the rate of deterioration in condition of lobsters is no different among locations and years on the NSW coast.

Methods

The Jervis Bay and Seal Rocks experiments

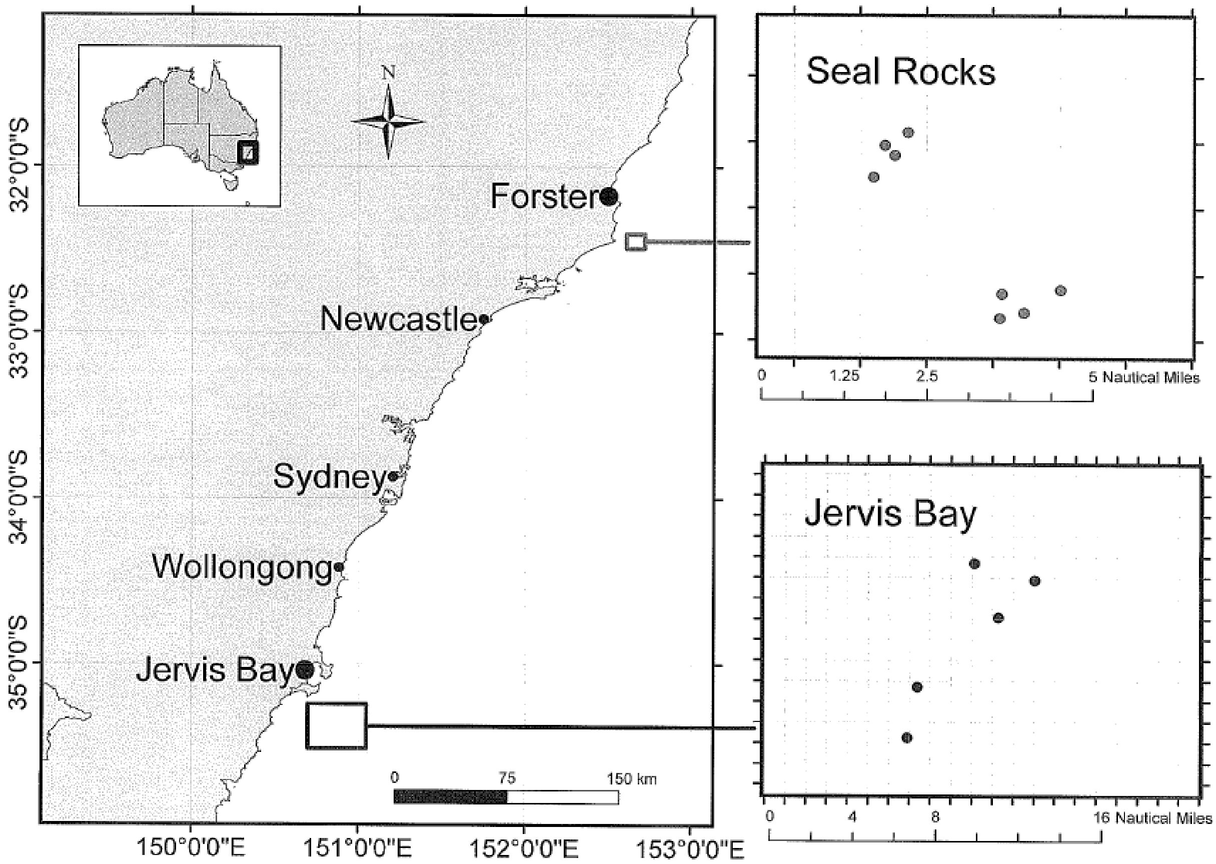
The experiment at Jervis Bay involved 5 replicate traps, set in depths of approximately 130 m (119 - 138 m), SE of Jervis Bay on the south coast of NSW (Fig. 1). The experiment at Seal Rocks involved 8 replicate traps, set on mid-shelf grounds, in depths of approximately 100 m (94 – 106 m), NE of Seal Rocks on the north coast of NSW (Fig. 1).

Each experiment comprised 2 phases. During an initial phase, traps were baited, subsequently lifted, re-baited and reset until sufficient lobsters were captured to commence the second, “simulated ghost fishing”, phase of the experiment. A single soak of baited traps was sufficient for immediate progression to the ghost fishing phase at Jervis Bay. In contrast, several baited soaks were required for the Seal Rocks experiment, due to a lesser abundance and catches of lobsters on these grounds at the time.

When sufficient lobsters were captured from the initial phase of each experiment, all lobsters in traps were tagged and the traps were reset with no bait to simulate a scenario of lost traps. During the subsequent 12 months, the traps were lifted and reset without bait, 4 times at Jervis Bay and 6 times at Seal Rocks, prior to final lifts at each location. The experiments were terminated when the deterioration of trap wire due to corrosion was such that the likelihood of the traps remaining intact for an additional soak was low.

At the completion of the initial “baited” phase and on each occasion traps were lifted during the phase simulating ghost fishing, each lobster in each trap was tagged with a uniquely numbered T-bar tag and a small v-notch was cut into the lobster’s uropod. The latter procedure was to distinguish “residents” from “new entrants” to the trap in case tags were lost during the course of the experiment. It was therefore possible, on each trap lift, to identify lobsters that were “new entrants” (no tag and no v-notch), “residents” (tag and/or v-notch) and “absentees” (lobsters missing since the previous lift). Gender and carapace length (mm CL) were also recorded.

Figure 1. Location of experiments simulating ghost fishing on mid-shelf fishing grounds off the coast of NSW.



Estimates of cumulative catch, residency, ingress and absentees

Estimates of the mean number of lobsters in traps and the mean numbers of residents, new entrants and absentees were calculated for each date on which traps were lifted. Estimates of means and associated 95% confidence intervals were based on linear model standardisation.

Condition of lobsters based on weight at length

At the conclusion of experiments at Jervis Bay and Seal Rocks, all lobsters recovered from traps were taken ashore for accurate measurement of individual weights. Based on the length of time these lobsters had been resident in traps, the condition of lobsters was compared: (i) among 3 residency periods (< 3 months; 3 –9 months; 9-12 months) and (ii) between Jervis Bay and Seal Rocks experiments. This was done using analyses of covariance that predicted weight based on the fixed factor "residency" (3 levels) and used length as a covariate.

Qualitative indices of condition

A simple qualitative assessment of the vigour of lobsters was made on the final lifts of traps during both the Jervis Bay and Seal Rocks experiments. The vigour of lobsters, in physically responding to being handled, was graded qualitatively as "active" or "non-active". Fisher's Exact tests were used to identify differences in frequencies of active and non-active responses among residency-periods (< 3 months; 3 –9 months; 9-12 months).

Results

Time-course of experiments

During the course of each experiment, several traps were lost prior to the scheduled end of the experiment. This may have resulted from several causes (e.g. cut-offs by shipping, vandalism, theft, whale collision), the very events that motivated this project (Tables 1 and 2).

At Jervis Bay, of the 5 traps that were originally set, 2 were not found after being lifted and reset at 185 days cumulative soak time. Of the 3 remaining traps, 2 were decommissioned (after 368 and 418 days) when it appeared unlikely they would last another soak. One trap that was reset at 368 days and lifted at 418 days had broken down and all lobsters had escaped (Table 1).

At Seal Rocks, of the 8 traps that were originally set, 1 was lost during the “baited soak” phase of the experiment, 2 traps were lost after being reset at 126 days, 1 after 300 days and 1 after 376 days cumulative soak time. The remaining 3 traps were decommissioned, and lobsters taken ashore, after a cumulative soak time of 427 days (Table 2).

Cumulative catches of lobsters

Following a single baited soak of 55 days duration, the 5 traps at Jervis Bay contained a mean 27.8 lobsters per trap (range: 14 – 44) (Fig. 2). Despite being reset with no bait, traps captured additional lobsters during the remainder of the summer fishing season. During the following winter months, the off-season, cumulative numbers of lobsters in individual traps were relatively stable. Numbers of lobsters decreased slightly in 2 traps and increased slightly in 1 trap. The cumulative number of lobsters in traps then increased markedly during the period October – December, the start of the following summer fishing season. The 3 traps remaining in the experiment on 15 December contained 75, 86 and 93 lobsters. The single trap that remained intact and was lifted after a further soak of 50 days, on 3 February, accumulated an additional 72 lobsters for a final total of 147 lobsters (Fig. 2).

Patterns of accumulation of lobsters in traps during the experiment at Seal Rocks were similar (Fig. 2). At the completion of the “baited soak” phase of the experiment, the 7 traps remaining in the experiment contained a mean of 9.4 lobsters (range: 3 – 23). Five of the 6 traps that were observed following the next 2 soaks toward the end of the summer fishing season accumulated additional lobsters. Through the winter months (off-season), cumulative numbers in traps were relatively stable with slight increases or decreases in individual traps. Cumulative numbers of lobsters in the 4 traps remaining for the next 2 soaks during spring (start of next fishing season) increased markedly with 30, 51, 57 and 60 lobsters in these traps on 29 November. Numbers of lobsters in the 3 traps observed on the final lift of the experiment on 19 January 2011 decreased marginally (Fig. 2).

Estimates of cumulative catch, residency, ingress and absentees

Standardised estimates (with 95% C.I.) of cumulative catch and numbers of residents, new entrants and absentees are shown in Figure 3 (Jervis Bay) and Figure 4 (Seal Rocks). In both experiments, traps caught lobsters during the 2-month (approx.) baited soak(s) in the first phase of the experiment. In both experiments, traps then continued to catch and accumulate lobsters over the 1-year (approx.) period of simulated ghost fishing. Based on the Jervis Bay experiment, traps that remained intact for a period of 368 days would have accumulated 82.6 (95% CI: 69.2 – 97.2) lobsters and those that remained intact for 418 days, 164.1 (95% CI: 130.3 – 201.8) lobsters (Fig. 3). Based on the Seal Rocks experiment, traps that remained intact for a period of 376 days would have accumulated 48.6 (95% CI: 37.9 – 60.6) lobsters and those that remained intact for 427 days, 43.6 (95% CI: 31.9 – 57.0) lobsters (Fig. 4).

Table 1. Time-course of events during the experiment simulating ghost fishing at Jervis Bay

S – set, L - lift

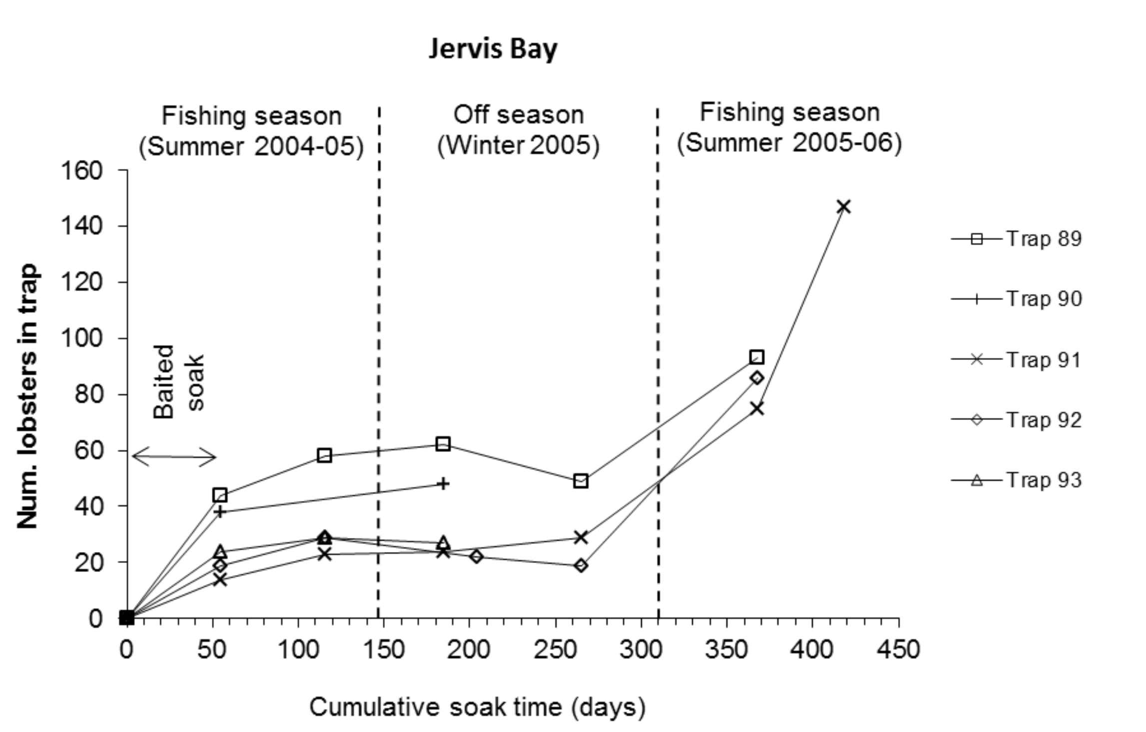
Set / Lift:	Baited set	Lift 0	Lift 1	Lift 2	Lift 3	Lift 4	Lift 5	
Date:	12/12/04	5/02/05	7/04/05	15/06/05	3/09/05	15/12/05	3/02/06	
Soak time (days):	0	55	61	69	80	103	50	
Cumulative (days):	0	55	116	185	265	368	418	
Trap ID								**Notes**
89	S	LS	LS	LS	LS	L		intact but breakdown iminent on 15/12/05 - not reset
90	S	LS	-	LS	-	-	-	last observed 15/06/05 - lost
91	S	LS	LS	LS	LS	LS	L	intact but breakdown iminent on 3/2/06 - not reset
92	S	LS	LS	LS	LS	LS	L & Broken	trap broken 3/2/06 - no lobsters
93	S	LS	LS	LS	-	-	L & Broken	not observed 3/9/05 or 15/12/05; broken on 3/2/06 - no lobsters

Table 2. Time-course of events during the experiment simulating ghost fishing at Seal Rocks.

S – set, L – lift

Set / Lift:	Baited sets	Lift 0	Lift 1	Lift 2	Lift 3	Lift 4	Lift 5	Lift 6	Lift 7	
Date:	18/11/09	28/01/10	22/02/10	24/03/10	10/07/10	14/09/10	21/10/10	29/11/10	19/01/11	
Soak time (days):	0	71	25	30	108	66	37	39	51	
Cumulative (days):	0	71	96	126	234	300	337	376	427	
Trap ID										**Notes**
191	S	LS	LS	LS	LS	LS	-	-	-	last observed 14/9/10 - lost
192	S	LS	LS	LS	LS	LS	LS	LS	L	intact but breakdown iminent on 19/1/11 - not reset
193	S	LS	LS	LS	LS	LS	LS	LS	L	intact but breakdown iminent on 19/1/11 - not reset
194	S	LS	LS	LS	LS	LS	LS	LS	L	intact but breakdown iminent on 19/1/11 - not reset
195	S	-	-	-	-	-	-	-	-	not observed since initial baited set
196	S	LS	-	LS	-	-	-	-	-	last observed 24/3/10 - lost
197	S	LS	LS	LS	LS	LS	LS	LS	-	last observed 29/11/10 - lost
198	S	LS	LS	LS	-	-	-	-	-	last observed 24/3/10 - lost

Figure 2. Cumulative catches of lobsters in traps over time at Jervis Bay and Seal Rocks



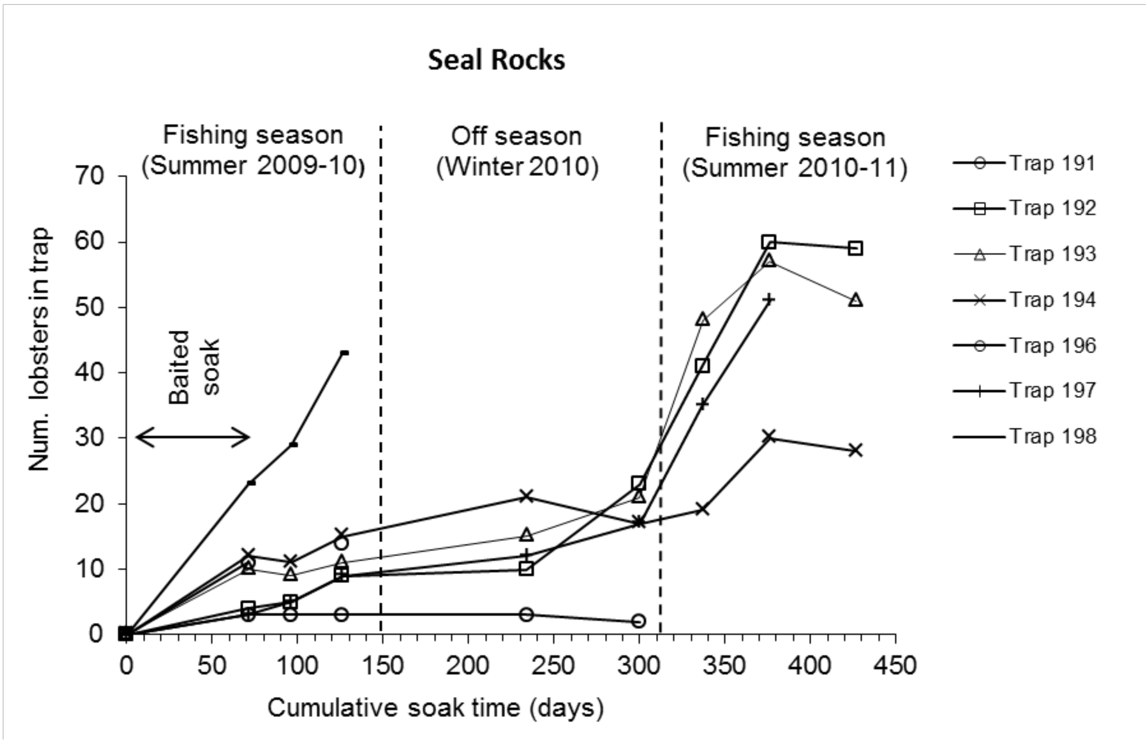


Figure 3. Estimated cumulative catch of lobsters and numbers of new entrants, residents and absentees (per trap, with 95% CI) over time, Jervis Bay experiment.

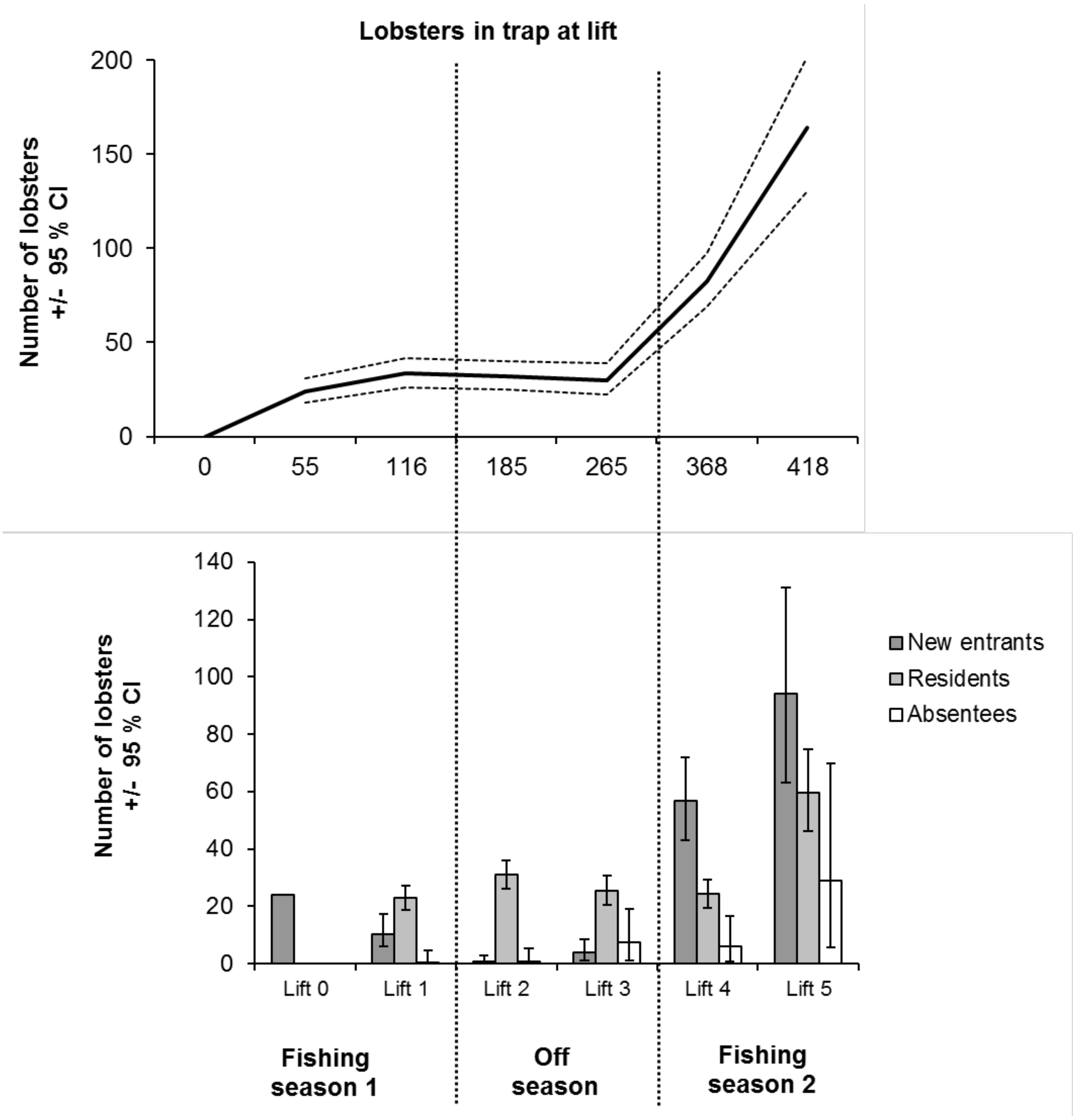
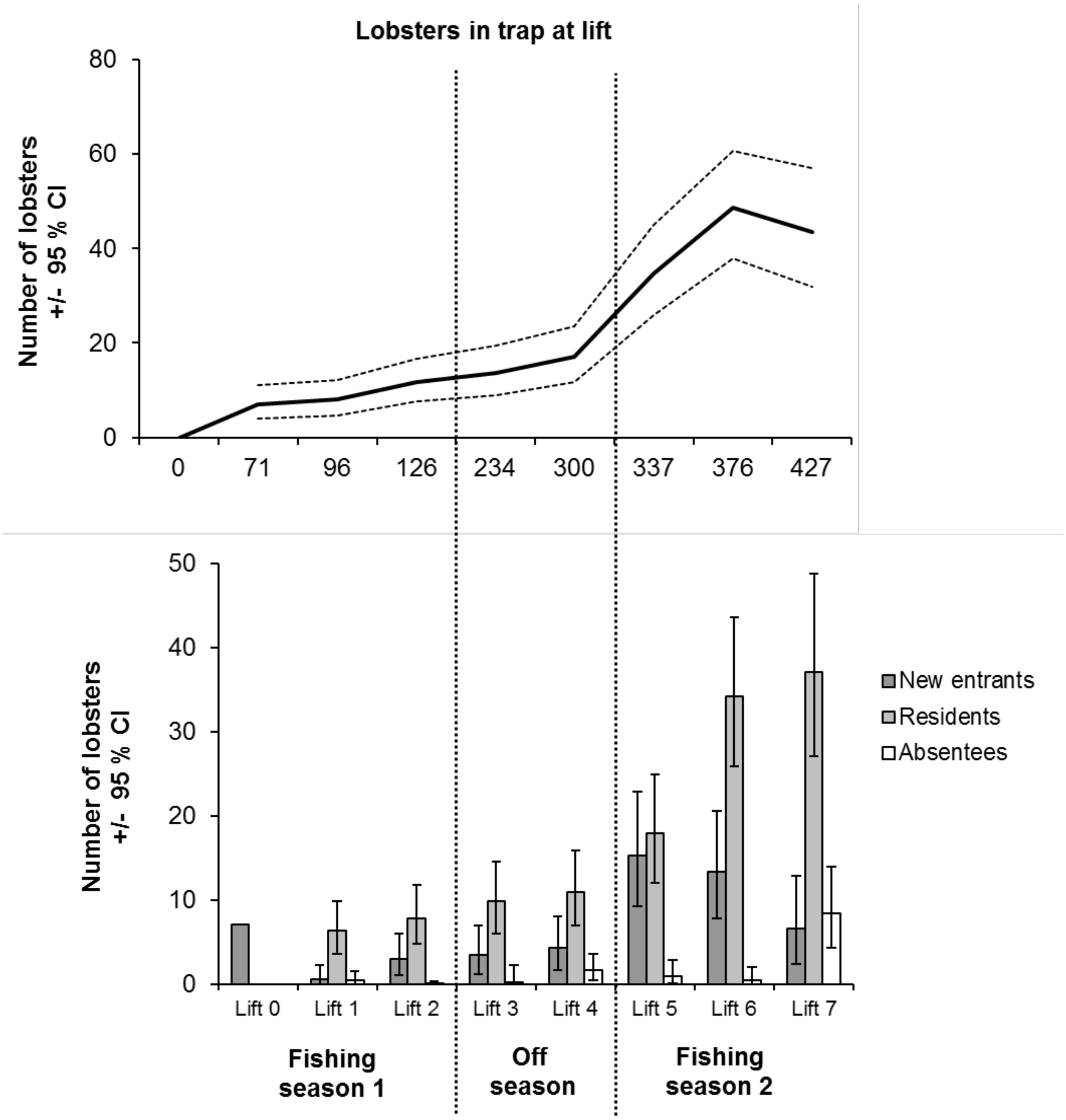


Figure 4. Estimated cumulative catch of lobsters and numbers of new entrants, residents and absentees (per trap, with 95% CI) over time, Seal Rocks experiment.



It was therefore a general result, from both experiments, that un-baited traps containing lobsters in mid-shelf depths off the coast of NSW continue to catch and accumulate lobsters. Evidence of ghost fishing is clear.

Rates of ingress of lobsters into traps differed over time in each experiment. At Jervis Bay, the number of new entrants to traps was greater during the summer periods at the start and finish of the experiment (summer 2004-05 and summer 2005-06) than during the intervening winter period (Fig. 3). At Seal Rocks, the number of new entrants to traps was greatest during the 2nd summer of the experiment (2010-11) than during the preceding summer (2009-10) or intervening winter (Fig. 4). Absentees reflect the combination of egress of lobster from traps and mortality of lobsters within traps. Estimated numbers of absentees from traps were greater during the latter stages of both Jervis Bay and Seal Rocks experiments (Figs. 3 and 4). For Jervis Bay, mean estimates for the first 3 trap-lifts prior were less than 1 lobster per trap-lift. During the latter half of the experiment, estimates of absentees from traps were 7.6 (95% CI: 1.3 – 6.3) lobsters for lifts at 265 days, 6.1 (95% CI: 0.7 – 16.8) lobsters at 368 days and 29.0 (95% CI: 5.8 – 69.7) lobsters for lifts at 418 days cumulative soak time. For the Seal Rocks experiment, mean estimates of absentees exceeded 1 lobster per trap lift on 2 lifts during the latter half of the experiment, 1.6 (95% CI: 0.4 – 3.6) lobsters after 300 days and 8.5 (95% CI: 4.3 – 14.0) lobsters after 427 days cumulative soak time.

Condition of lobsters based on weight at length

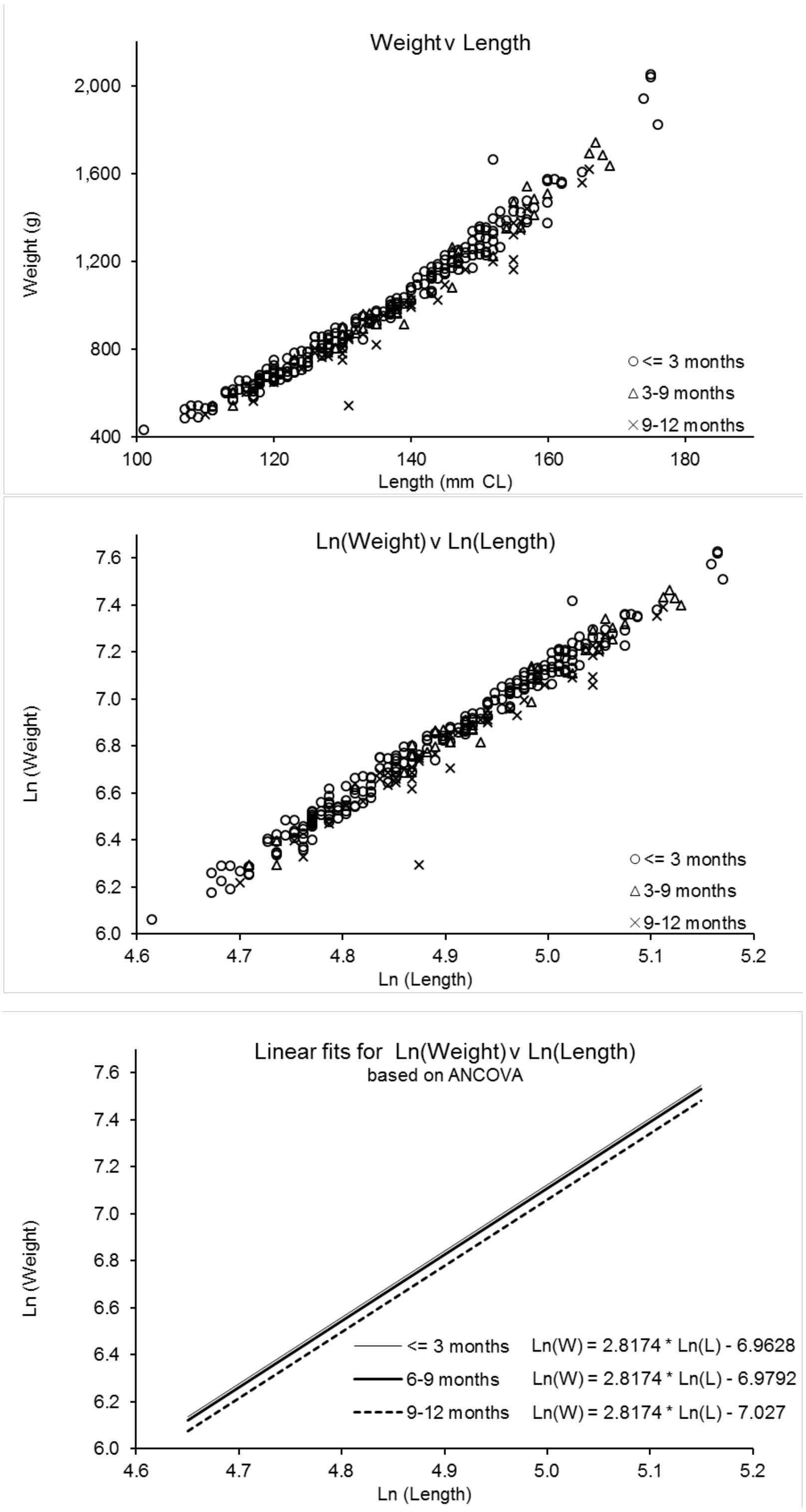
A total of 240 lobsters were retrieved from the 2 traps that were still intact but not re-set at the end of the Jervis Bay experiment. Weights (measured onshore) were available for the majority of these lobsters excluding some of the new entrants to these traps that were given to the commercial fisher who provided his vessel free of charge for the experiment. Note that these lobsters were treated as commercial catch by the fisher, tagged with management tags and declared in the commercial logbook. Also, residency-time could not be determined for several lobsters that had lost their tags. For 171 lobsters, weight and residency time were known. A total of 138 lobsters were retrieved from the 3 traps that were still intact but not re-set on termination of the Seal Rocks experiment and both weight and residency-time were known for 137 lobsters.

Thus, available for this analysis, there were 171 lobsters from Jervis Bay and 137 from Seal Rocks with residency-times ranging from 0 to 363 days. Note that these times are underestimates because they were based on the number of days between the date at which the lobster was first detected in the trap (and tagged) and the date the experiment was terminated.

Based on the ANCOVA, there was no significant difference in the length-weight relationship due to location of the experiment (Jervis Bay v Seal Rocks; $P = 0.080$). There were significant differences among the 3 levels of residency-time ($P < 0.001$). For any given length, lobsters that were resident in traps for periods of 9-12 months weighed 6.4% less than lobsters that were resident in traps for < 3 months ($P < 0.001$) and 4.8% less than lobsters had been resident for 3 – 9 months. There was, however, no significant difference in weight between lobsters in traps for < 3 months and those in traps for 3-6 months (Difference = 1.6%, $P = 0.15$) (Fig. 5).

Condition of lobsters, based on weight at length, resident in traps for periods greater than 9 months was significantly worse than those that had been resident for lesser periods.

Figure 5. Length-weight relationship for lobsters resident in traps for periods < 3 months, 3-9 months and 9-12 months. Lobsters from Jervis Bay and Seal Rocks experiments pooled.

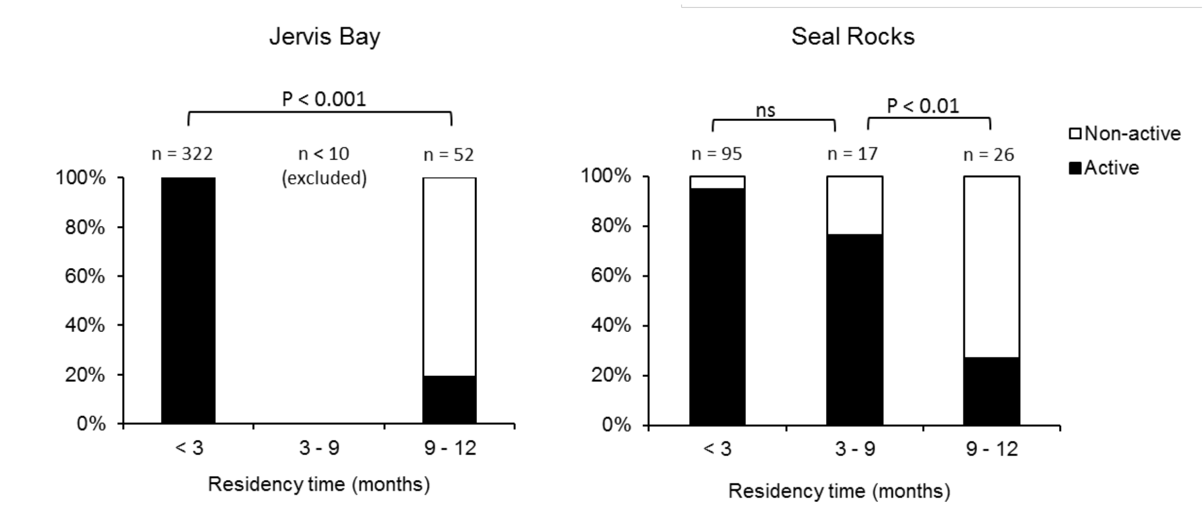


Qualitative indices of condition

A simple qualitative assessment of the vigour of lobsters was done on the final lifts of traps during both the Jervis Bay (2 traps: trap-89 and trap-91; see Table 1) and Seal Rocks (3 traps: trap-192, trap-193 and trap-194; see Table 2) experiments. Lobsters were also assessed for 1 additional trap at Jervis Bay (trap-92 on 15/12/2005) on its penultimate lift. This was done because the likelihood of trap breakdown before the next scheduled lift was apparent at this time. Indeed, this trap was no longer intact and contained no lobsters on its final lift (Table 1)..The physical vigour of lobsters, in response to being handled, was graded qualitatively as “active” or “non-active”. Both this index of activity and residency-time were available for 374 lobsters from the Jervis Bay experiment and 138 lobsters from the Seal Rocks experiment.

Only 10 of 52 lobsters resident in traps for longer than 9 months at Jervis Bay were graded as “active”. In contrast, a significantly greaterproportion of lobsters that were resident in traps for less than 3 months (320/322 lobsters) were assessed as “active” (Fisher’s Exact P<0.001) (Fig. 6). Results from the experiment at Seal Rocks were similar. Only 7 of 26 lobsters resident for longer than 9 months were “active” compared to the majority of lobsters that were resident for periods 3-9 months (13/17; Fisher’s Exact P < 0.001) and less than 3 months (90/95; Fisher’s Exact P < 0.01) (Fig. 6).

Figure 6. Qualitative indices vigour for lobsters resident in traps for periods < 3 months, 3-9 months and 9-12 months.



Conclusions

Rock lobster traps fished in mid-shelf depths off the coast of NSW at both Jervis Bay and Seal Rocks continued to catch and accumulate lobsters (ghost-fishing) until their structural integrity was compromised after approximately 14 months.

The condition of lobsters, based on both weight at length and a qualitative index of vigour, deteriorated over time at both Jervis Bay and Seal Rocks. Weight at length and indices of vigour decreased significantly for lobsters resident in traps for periods greater than 9 months.

Utility of sacrificial panels in traps to minimise ghost fishing

Introduction

The experiment presented here addresses the project objective “Design and test modifications to traps that facilitate the escape of lobsters from lost traps prior to mortality”. It concerns the performance of alternative designs of sacrificial panel – specifically, the time taken for these alternative designs to break down and facilitate the escape of lobsters.

Lobster traps used in mid-shelf and outer-shelf depths off the NSW coast are typically large rectangular- prism timber-framed traps approximately 1.8 m in the longest dimension. Wire mesh is wrapped around the top, bottom, sides and back panels of the trap. The front panel of the trap (the “door”) is removable from the trap and is constructed on a separate rectangular timber frame and the wire mesh is stapled to this frame. These traps typically have 3 entrances (“nozzles”) for lobsters, one on each side of the trap and one in the removable front panel. The wire in this front panel is isolated from the wire wrapped around the other 5 panels of the trap. Several sacrificial aluminium anodes are attached to the wire on the trap, including the front removable panel, to extend the effective life of the trap. The aluminium anodes undergo galvanic corrosion, thereby providing cathodic protection of the trap wire.

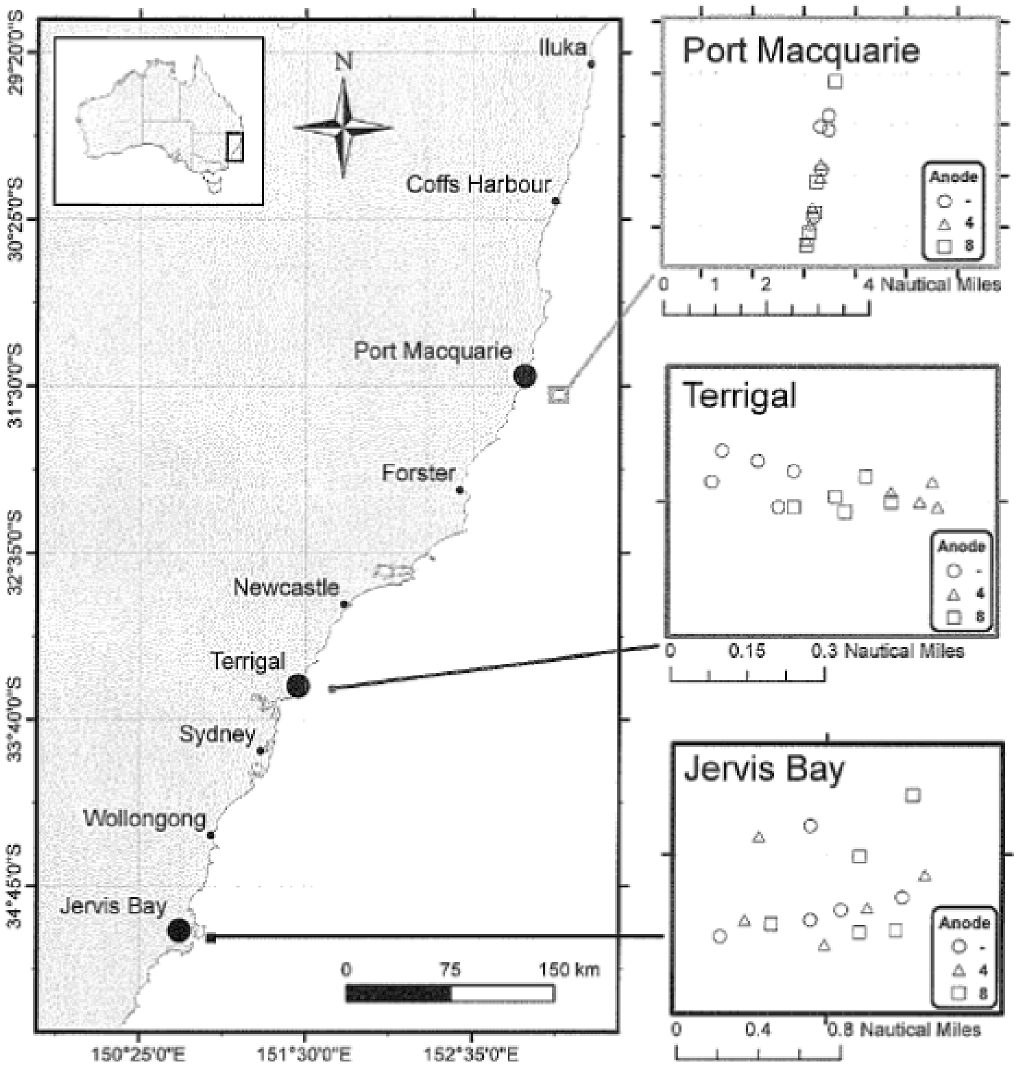
Because the wire mesh in the removable front panel of the trap is electrically isolated from the wire mesh in the remainder of the trap, this front panel may potentially be used as a sacrificial panel that corrodes and allows the escape of entrapped lobsters. The experiment described here was designed to estimate the breakdown time for sacrificial panels with 3 alternative levels of galvanic protection (single 20 cm anode, a single 10 cm anode and no anode). To assess whether breakdown times for these treatments were consistent among locations, the experiment was done at 3 locations on the NSW coast. The influence of 2 factors that may potentially influence breakdown-time, (i) water temperature and (ii) abrasion of wire mesh by lobsters and hermit crabs, were also considered in the experimental design.

Methods

At each of 3 locations (Jervis Bay, Terrigal and Port Macquarie; Fig. 7), 15 traps were fished on mid-shelf grounds by commercial fishers. At each location, 5 traps were control traps with a 20 cm aluminium anode on the sacrificial panel (trap door) as is usual practice. The other 10 traps were identical in all respects except that 5 traps had 10 cm aluminium anodes attached to the trap door and there was no anode attached to doors of the remaining 5 traps.

The experiment commenced when traps were set on recognised mid-shelf fishing grounds off: Jervis Bay (102 – 125 m depth) in September 2009; Terrigal (110 – 120 m depth) in October 2009; and Port Macquarie (80 – 93 m) in March 2010. At each location, the traps were fished by the commercial fisher according to their usual routine and practices. This typically resulted in soaks of 3 – 4 weeks at Jervis Bay, 4 – 6 weeks at Terrigal and an initial soak of about 12 weeks followed by 4 – 8 week soaks at Port Macquarie. As these traps were being fished commercially by the fishers, lobsters and bycatch were removed from the traps at each lift and the traps were then rebaited and reset.

Figure 7. Location of experiments assessing the performance of alternative designs of sacrificial panel.



On each occasion that traps were lifted, operational data (date, time, depth, latitude & longitude), data describing the catch (number of lobsters, weight of hermit crabs, weight of other bycatch) and data documenting the condition of wire mesh in the trap-door (sacrificial panel) and the rest of the trap were recorded. The condition of the trap wire was separately assessed for:

(i) staples that fix the wire mesh to the frame;

(ii) wire under the staples;

(iii) wire in the nozzle;

(iv) wire where the nozzle is "twitched" into the wire mesh panel;

(v) wire in the main body of the panel.

The condition of the wire was graded on a 4-point scale:

0 – structurally intact and no/slight discolouration;

1 – structurally intact but with slight corrosion;

2 – structurally intact but with heavy corrosion;

3 – breakages.

An estimate of the proportion (%) of the original mass of the attached anode(s) was also recorded.

Water temperature loggers (Brand: Star-Oddi, Model: Centi T) were attached to 2 randomly selected traps at each location for the duration of the experiment. Loggers were programmed to record water temperature at 30-minute intervals for the duration of the experiment. Data was retrieved from the loggers every 2-3 months over the course of the experiment.

The experimental design and methodology facilitates testing several hypotheses: (i) sacrificial panels with no anodes to provide protection against galvanic corrosion of wire in the panels break down more quickly than those with 10 cm aluminium anodes which, in turn, break down more quickly than those with 20 cm aluminium anodes; (ii) there is no significant difference in the catches of lobsters from traps using the 3 designs of sacrificial panel; and (iii) lobsters resident in traps escape following breakdown of the sacrificial panel. In additional to these core hypotheses, the relationship between trap-breakdown time and (i) water temperature and (ii) the "abrasive load" or quantity of lobsters and hermit crabs is considered.

Analyses

The date at which a sacrificial panel was deemed to have "broken down" was the date midway between the date on which a component of the panel was first observed to be broken (grade 3) and the preceding observation date. The breakdown time (or effective longevity) of a panel was estimated to be the number of days between initial deployment and the deemed date at which breakdown occurred. Consequently, there is a margin of error around the estimated breakdown time that is typically +/- 1 month. For example, one of the no-anode panels at Jervis Bay was still intact (no wire breakages) after 159 days but was subsequently observed with multiple wire breakages after 216 days, 57 days after the previous observation. In this example, the deemed date at which breakdown occurred was 57/2 = 28.5 days prior to the date of final observation and the breakdown time was estimated to be 216 – 28.5 = 187.5 days.

The experiment was terminated at Jervis Bay after 336 days, when all experimental panels in the no-anode and 10cm-anode treatments had broken down. The experiments at Port Macquarie and Terrigal were terminated after 305 and 463 days respectively, at which time the non-anode experimental panels had broken down but the 10cm-anode and 20-cm anode panels showed minimal deterioration and were going to outlast the rest of the trap. Mean breakdown time was compared among the 3 locations for the no-anode treatment using 3 two-sample t-tests (for heterogeneous variances). Mean breakdown time was compared between the no-anode and 10cm-anode treatment for Jervis Bay using a two-sample t-test (for heterogeneous variances). To maintain the family-wise Type-I error rate at $P = 0.05$, the conservative Bonferroni procedure was used whereby the 4 individual t-tests were done using a critical-P of $0.05/4 = 0.0125$.

Mean daily water temperature was calculated from the 30-minute logged values recorded by each of the 2 temperature loggers at each location. Daily water temperatures were compared between the 2 loggers within each location and among the 3 locations.

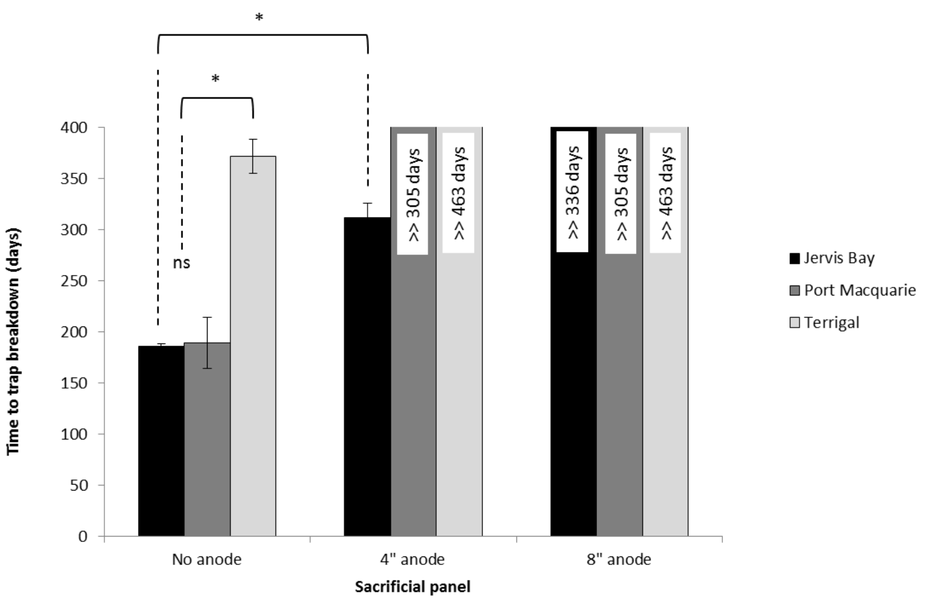
The number of "lobster-days" and "hermit-crab-days" experienced by each of the traps with no anode on the sacrificial panel was estimated. It was assumed that the lobsters and hermit crabs that were captured in a trap had, on average, entered that trap half-way through the soak of the trap. Thus, for each soak of a trap, the "abrasive load" of lobsters or hermit crabs was calculated as the number of lobsters or hermit crabs captured multiplied by half the soak time. The cumulative number of lobster-days (Lob-days) and hermit-crab-days (HC-days) during the first 4 months (approx.) of the experiment was then calculated for each trap to provide an index of the abrasive load on the wire in each trap. The relationship between mean abrasive load due to lobsters and/or hermit crabs and trap breakdown for each location was examined.

Results

Longevity of sacrificial panels

No-anode panels lasted approx. 6.1 months at Jervis Bay (mean 186.1 +/- 2.1 days, n = 4, 1 trap lost), 6.2 months at Port Macquarie (mean 189.6 +/- 25.1 days, n=4, 1 trap lost) and 12.2 months at Terrigal (372.1 +/- 17.0 days, n = 5) (Fig. 8). There was no significant difference in the mean breakdown time for no-anode panels at Jervis Bay and Port Macquarie (t-test, p = 0.45 > crit. 0.05/4). In contrast, no-anode panels on traps at Terrigal remained intact for a significantly greater period than those at Jervis Bay and Port Macquarie (Terr. v JB: t-test, p = 0.0002 < crit. 0.05/4; Terr. v PM: t-test, p = 0.0005 < crit. 0.05/4) (Fig. 8).

Figure 8. Mean (+/- 1 se) longevity of sacrificial panels (3 treatments: no anode, 10 cm anode, 20 cm anode) for experiments at Jervis Bay, Port Macquarie and Terrigal.



Experimental panels protected by 10 cm anodes lasted approximately 10.3 months (mean 312 +/- 14.0 days, n = 4, 1 trap lost) months at Jervis Bay. These panels remained intact for a significantly greater period than the no-anode panels at the same location (t-test, p = 0.001 < crit. 0.05/4) (Fig. 8). When the experiment was terminated at Port Macquarie (after 305 days) and Terrigal (after 463 days), all panels protected by 10cm anodes remained intact. Thus, experimental panels protected by 10 cm anodes remained intact for greater than 10 months at Port Macquarie and greater than 15 months at Terrigal.

Experimental panels protected by 20 cm anodes remained intact for the duration of the experiment at all locations (336 days at Jervis Bay, 305 days at Port Macquarie and 463 days at Terrigal).

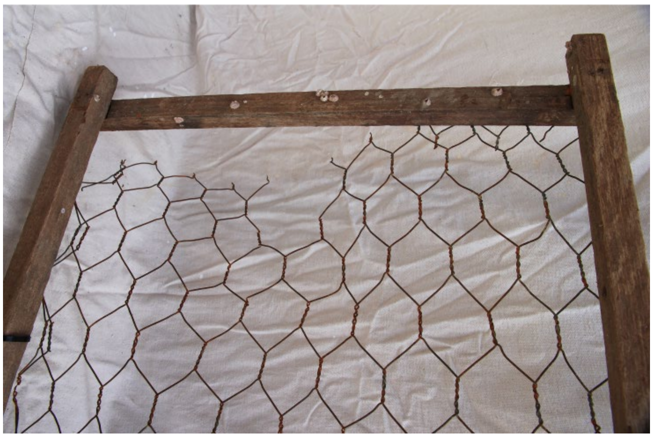
Corrosion of panel components

In all of the observed instances of sacrificial panel break-down, the staples that secure the panel wire to the door frame and/or the section of wire underneath the staples were the first components of the panel to corrode away (Fig. 9) Figure 9 illustrates the result of this corrosion on one of the sacrificial panels with no anode, after 6-7 months of the experiment

Figure 9. Sacrificial panel (no-anode trap door) after corrosion resulted in breakages of wire that allowed escape of lobsters

The entire panel with breakages of wire along the left-hand edge

Close-up of the breakages along the left-hand edge

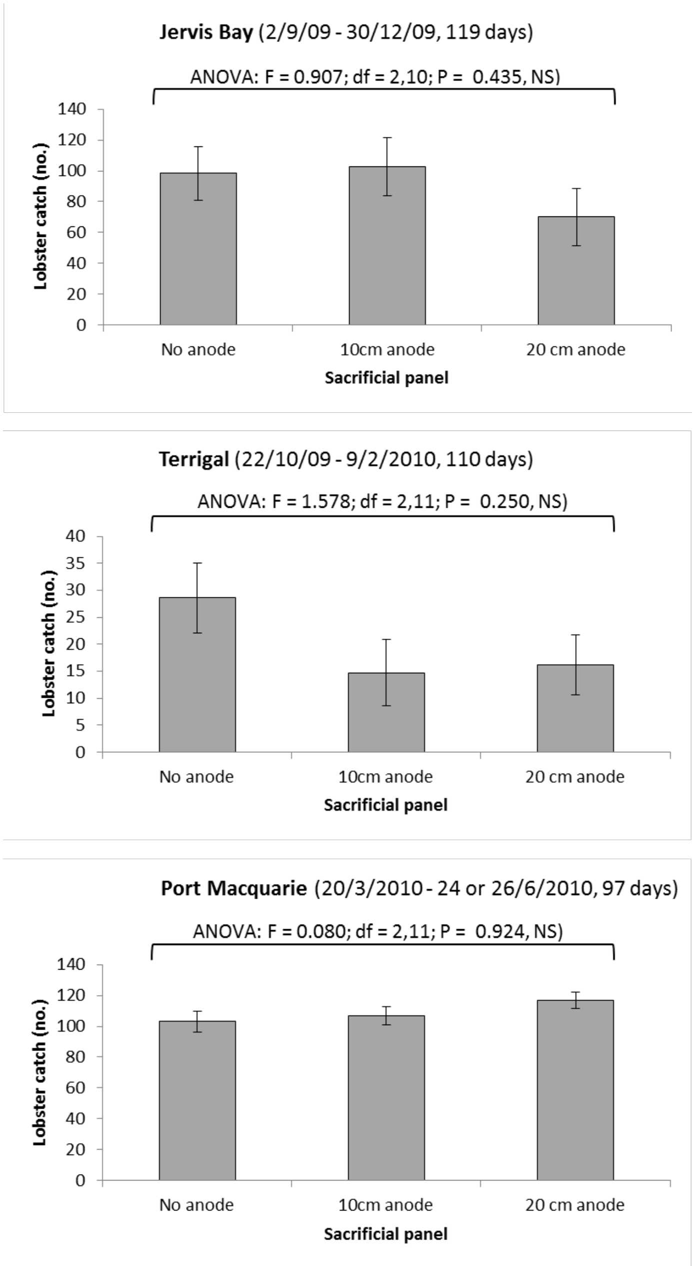


Galvanic corrosion of staple and wire under staple that secures the wire to the frame of the panel

Comparative catch rates of lobsters among the 3 designs of sacrificial panel

There was no difference in mean catch rates of lobsters among the 3 experimental treatments at any of the 3 locations (single factor ANOVAs: Jervis Bay P = 0.43, df = 2,10; Terrigal P = 0.25, df = 2,11; Port Macquarie P = 0.92, df = 2,11; Fig. 10).

Figure 10. Catch rates of lobster (+/- 1 se) for 3 experimental sacrificial panel treatments (no-anode, 10cm-anode and 20cm-anode) for each of 3 locations.



Escape of lobsters through broken down sacrificial panels

As expected, traps with sacrificial panels that had broken down, contained no (or very few) lobsters on the final lift. The 4 traps with no-anode panels at Jervis Bay did not contain any lobsters on their final lift. At Terrigal, 4 of the 5 traps with no-anode panels contained no lobsters and one trap contained a single lobster. At Port Macquarie, 3 of the 4 traps with no-anode panels contained no lobsters and one trap contained 2 lobsters. In contrast, the 4 traps with 10cm-anode panels that had broken down at Jervis Bay each contained between 1 and 15 lobsters. These traps were defined as "broken down" because wire components in the sacrificial panel had corroded away (e.g. 1 or 2 staples or the wire under 1 or 2 staples). Gaps in the wire mesh or between the wire mesh and the frame were, however, not yet large enough to allow the escape of lobsters.

Evidence of the escape of lobsters from broken down traps comes from the Jervis Bay experiment because lobsters were abundant during the weeks prior to the breakdown of the traps with no-anode sacrificial panels. Traps in the 10cm-anode and 20-cm anode treatments (all with intact sacrificial panels), that were observed on the same dates (matching final lift and preceding lift dates) as the traps with broken down sacrificial panels, caught many lobsters during the equivalent period (Table 3).The possibility that lobsters escaped from or fell out of the traps in the no-anode treatment during hailing can be discounted because the hauling rope was attached to bridles on the front of the trap where the sacrificial panel (trap door) was located. Lobsters fall into the back of the trap or cling to the trap wire during hauling. The wire in all panels of the traps in the no-anode treatment, other than the experimental front panel was intact on the final lift. It is therefore concluded that the 4 traps in the no-anode treatment also contained lobsters during their final soak but that they escaped the trap following breakdown of the sacrificial panel.

Table 3. Catch of lobsters from broken down, no anode, sacrificial panels versus traps with intact panels (10cm- and 20cm-anode treatments) with matching dates.

Traps with no anode on sacrificial panel						Other intact traps with equivalent observation dates		
Trap ID	Final Observation Date	Preceding Observation Date	Estimated Breakdown Date	Deemed Breakdown Time (Days)	Num. Lobsters on final lift	Num. traps	Lobster catch (Mean +/- SE)	
926	20/05/2010	30/12/2009	10/03/2010	189.5	0	8	115	22
929	6/04/2010	24/01/2010	1/03/2010	180.0	0	5	60	16
932	6/04/2010	8/02/2010	8/03/2010	187.5	0	6	36	9
935	6/04/2010	8/02/2010	8/03/2010	187.5	0	6	36	9

Water temperature and the longevity of sacrificial panels

Within each location, daily water temperatures did not differ substantially between the 2 loggers deployed on traps. The mean absolute difference in daily temperature between the 2 loggers within each location was 0.14ºC (SD 0.16) at Port Macquarie, 0.14ºC (SD 0.18) at Terrigal and 0.08ºC (SD 0.08) at Jervis Bay. Consequently, temperature profiles recorded by the 2 loggers within each location were virtually identical over the course of the experiment (Fig. 11). It is therefore reasonable to conclude that all traps within each location experienced the same water temperature over the duration of the experiment. Day to day, week to week and month to month variations in water temperature are apparent at each location.

Mean temperature experienced by the traps during the first 6 months (182 days) of the experiment was 16.7ºC at Port Macquarie, 15.1ºC at Terrigal and 14.5ºC at Jervis Bay. Mean temperature decreased with increasing southern latitude (Fig. 11). There was no relationship between mean water temperature and the breakdown time of no-anode sacrificial panels at each location (Fig. 12).

Figure 11. Mean daily water temperature experienced by 2 traps at each of Port Macquarie, Terrigal and Jervis Bay during the sacrificial panel experiment.

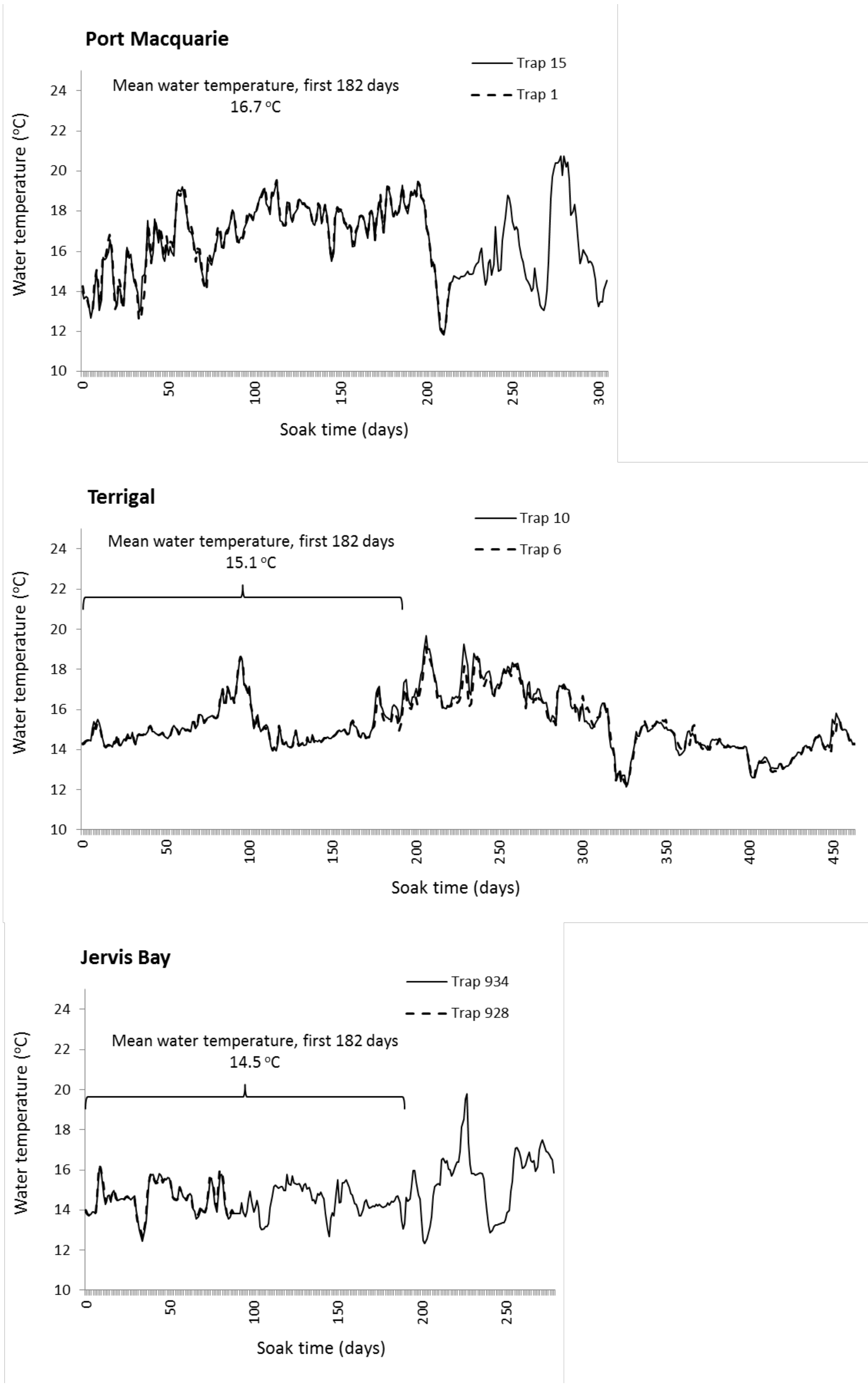
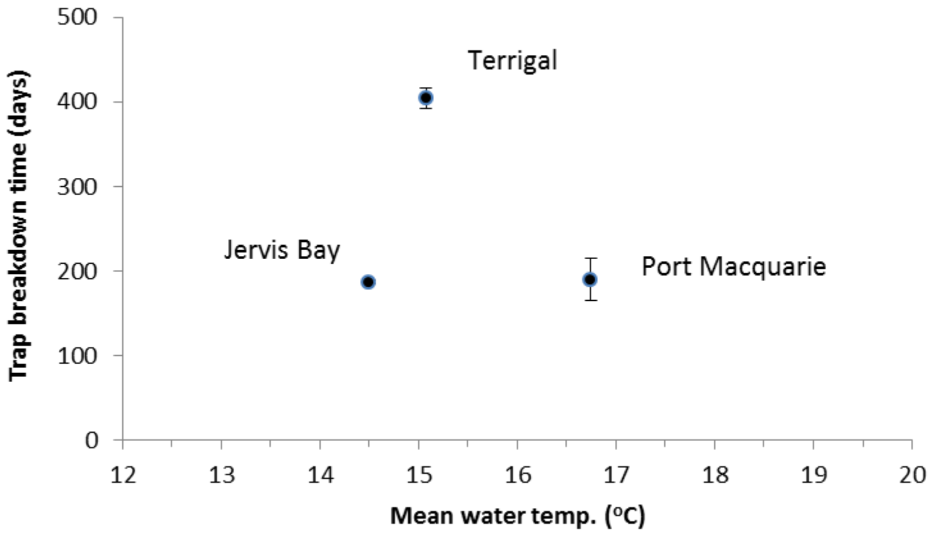


Figure 12. Mean breakdown time for sacrificial panels (treatment: no anode) versus mean (+/- 1 se) water temperature experienced by traps during the first 6 months of the experiment at the 3 locations (Port Macquarie, Terrigal and Jervis Bay) during the sacrificial panel experiment.

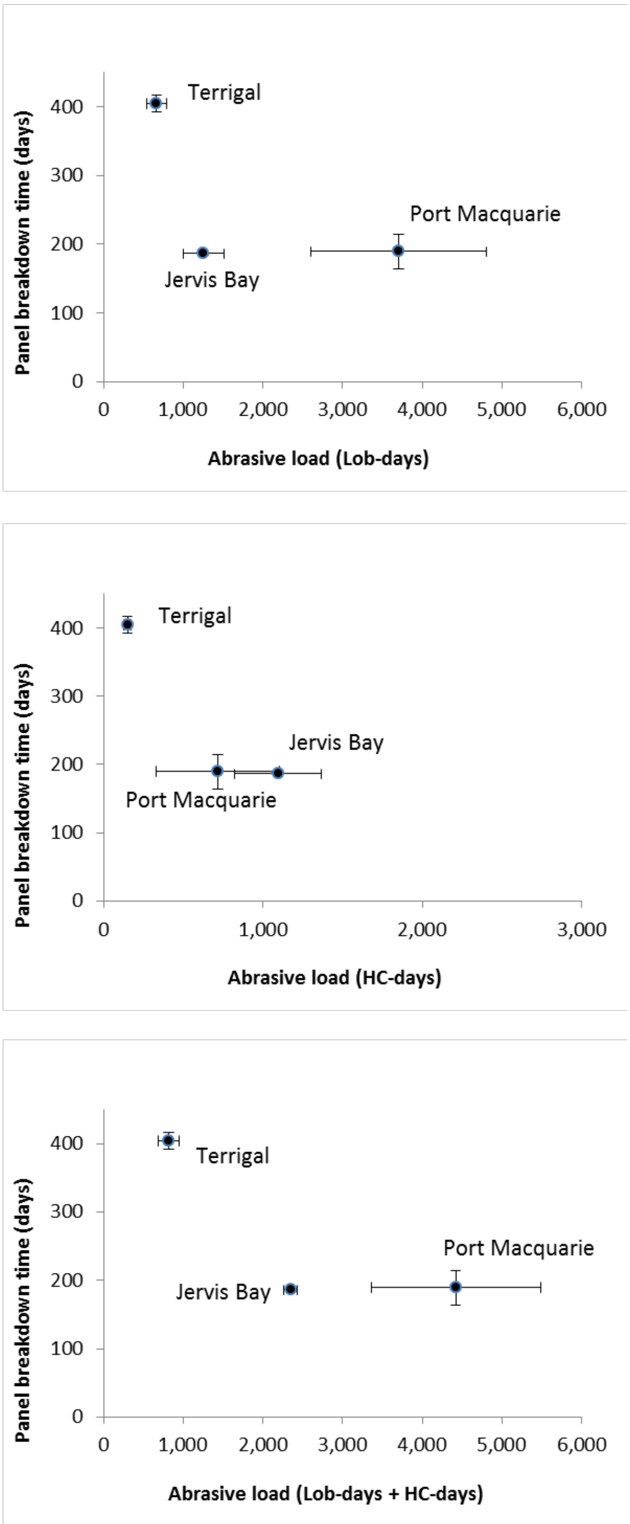


Abrasive load of lobsters, hermit crabs and the longevity of sacrificial panels

The traps at Terrigal experienced the least abrasive load due to lobsters (666 +/- 128 lob-days) compared to Jervis Bay (1,255 +/- 256 lob-days) and Port Macquarie (3,706 +/- 1103 lob-days). Abrasive load due to hermit crabs was lowest at Terrigal (149 +/- 23 HC-days) compared to Port Macquarie (717 +/- 385 HC-days) and Jervis Bay (1,095 +/- 274 HC-days). Consequently, the abrasive load due to lobsters and hermit crabs combined was also lowest at Terrigal (815 +/- 136) compared to Jervis Bay (2,350 +/- 85) and Port Macquarie (4,423 +/- 1,061).

The lower catches of lobsters and hermit crabs and consequent lower indices of abrasive load for traps at Terrigal, compared to the 2 other locations, was associated with greatest breakdown time for the sacrificial panels unprotected by an anode (Fig. 13). This suggests the possibility that the time taken for wire in the sacrificial panels to corrode may partially be influenced by physical abrasion of the exoskeletons of lobsters and hermit crabs and the shells of hermit crabs.

Figure 13. Mean (+/- 1 se) breakdown time for sacrificial panels (treatment: no anode) versus abrasive load (+/- 1 se) with abrasive load based on lobster-days ("Lob-days", top panel), hermit-crab-days ("HC-days", middle panel) and "Lob-days + HC-days" (bottom panel).



Conclusions

Sacrificial panels unprotected from galvanic corrosion by sacrificial anodes break down more quickly than those with 10 cm aluminium anodes which, in turn, break down more quickly than those with 20 cm aluminium anodes.

The breakdown time for sacrificial panels unprotected by anodes and those with a 10 cm anode attached varied substantially among the trials done at 3 locations (Jervis Bay, Terrigal and Port Macquarie).

The staples that secure the panel wire to the door frame and the section of wire underneath the staples were the first components of the sacrificial panel to corrode and fail.

Catch rates of lobsters (per trap-lift) were not affected by the 3 designs of sacrificial panel.

Lobsters escaped from traps following breakdown of the sacrificial panels.

There was no relationship between mean water temperature and the breakdown time of sacrificial panels for the 3 locations.

Traps at the location at which sacrificial panels had the greatest longevity (Terrigal) caught significantly lesser quantities of lobsters and hermit crabs. This suggests the possibility that physical abrasion of panel wire due to the presence of lobsters and hermit crabs may influence corrosion and breakdown time.

The main factors responsible for the observed differences in breakdown time of traps among the 3 locations remain unclear.

The substantial variation in the speed of corrosion and consequent breakdown time of sacrificial panels among locations severely limits the potential for implementing a standard design of sacrificial panel across the fishery. Further investigation and understanding of factors affecting corrosion and breakdown time and associated spatial and temporal variation is unlikely to alter this conclusion.

Application of acoustic release technology to reduce trap loss

Introduction

Acoustic release technology has been used in a variety of applications (e.g. oceanographic monitoring and research) to provide access to equipment deployed on the sea-floor. It has, however, not previously been used for any commercial fishing activity. It has potential application for high-value fisheries in which gear is set on the sea-floor with access to the head-gear (rope and floats) providing surface access to the gear. Loss of head-gear may result from (i) cut-offs by commercial shipping and other vessels; (ii) theft of traps and product; (iii) vandalism; or (iv) interactions with large marine creatures (e.g. whales). Loss of access to fishing gear has economic consequences for fishers and may result in ghost fishing of the gear, imposing an additional unaccounted fishing mortality on the species captured.

The use of sacrificial panels in traps represents a means to minimise ghost fishing after a trap is lost. In contrast, the use of acoustic release technology provides a potential means to minimise loss of traps in the first place. This directly relates to the 3rd objectives of this project: Develop and test alternative methods for the setting of traps and deployment of head-gear to reduce mortalities of lobsters resulting from ghost fishing and theft.

The potential of the ARC-1XDf acoustic release system, manufactured by Desert Star Systems in the USA, was evaluated during this project. The objective was to provide proof of concept and proof of application with respect to the capability of this system to provide at-call access to submerged head-gear of deep-water lobster traps used in the NSW fishery.

Methods

Application and integration of the Desert Star ARC-1XDf acoustic release system

The Desert Star ARC-1XDf system comprises multiple submersible release-units and surface-based control units and software. Based on the equipment that NSW lobster fishers use to submerge the head-gear of traps inside plastic mesh bags, a system of integrating acoustic releases was designed. A brief description is provided here.

The surface station comprises a laptop computer, software that controls the acoustic release system, a surface transmitter module (STM) and one or two transducers (Fig. 14). The software running on the laptop allows the user to issue commands, communicate with and control the release units and performs record keeping of deployed and released ARC release units (Fig. 15). The ARC-1XDf release unit is attached to a plastic mesh bag that contains the head-gear (rope and floats). The floats are retained in the bag by a release cord that is attached to the release lever on the release unit, runs through a series of stainless steel links, over the top of the floats, to a “backup” GTR on the other side of the bag (Figs. 16 & 17). The top end of the release unit contains a transducer to receive and send signals to the surface station. The release lever at the bottom end of the unit retains a loop of the release cord and is held closed by a 26 AWG nickel chromium alloy wire secured between 2 posts (Fig. 18). When a release command is sent to the unit, a capacitor is charged which then passes a current at high voltage through the burn wire causing it to combust. This allows the release lever to open, the release cord to be pulled free and the floats and trailing rope to exit from the bag to the surface.

Figure 14. Components of the ARC surface station: laptop computer with ARC control software (left), surface transmitter module (right), multi-directional transducer (bottom centre) and through-hull transducer (bottom right).

Figure 15. ARC software display screen: menu bar, release-unit serial number (SN), set/deploy location, deploy and release buttons, range field, vessels current GPS location, signal strength %, range for the given ARC release-unit, i. time and date of deployment, user comments and current status display field.

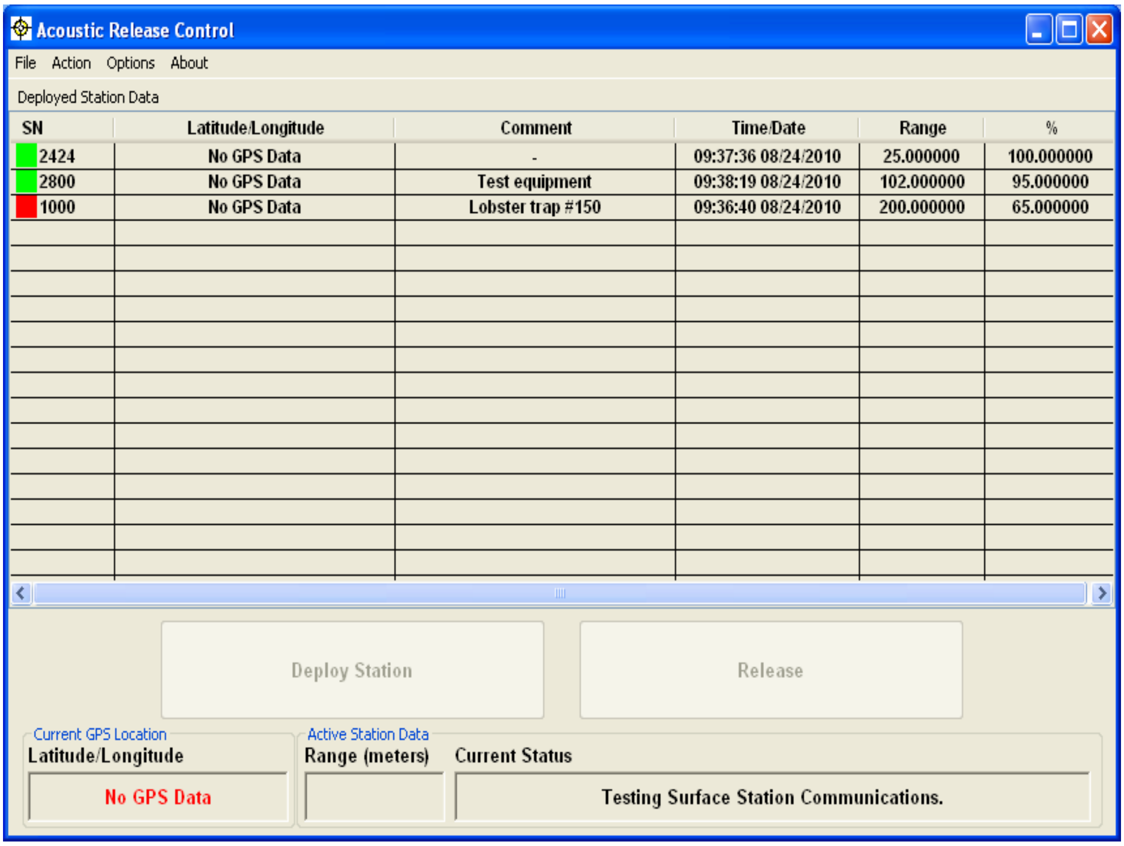
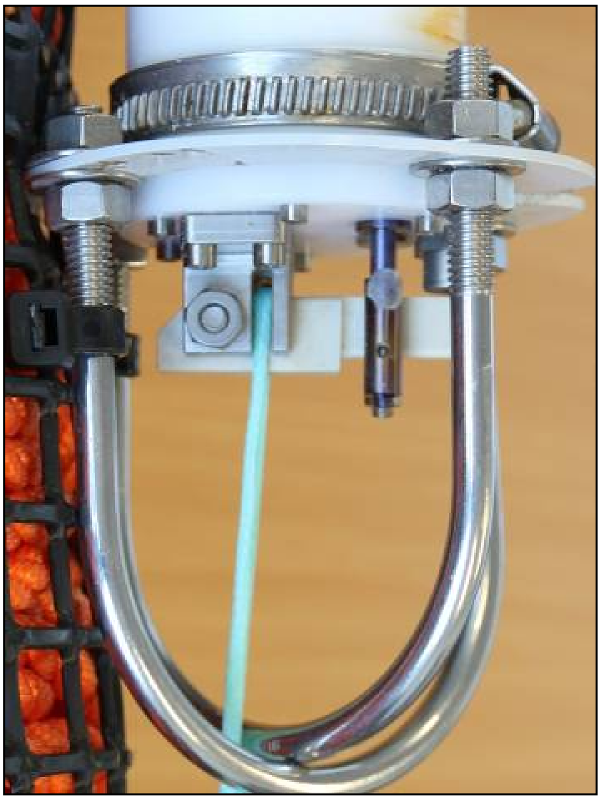
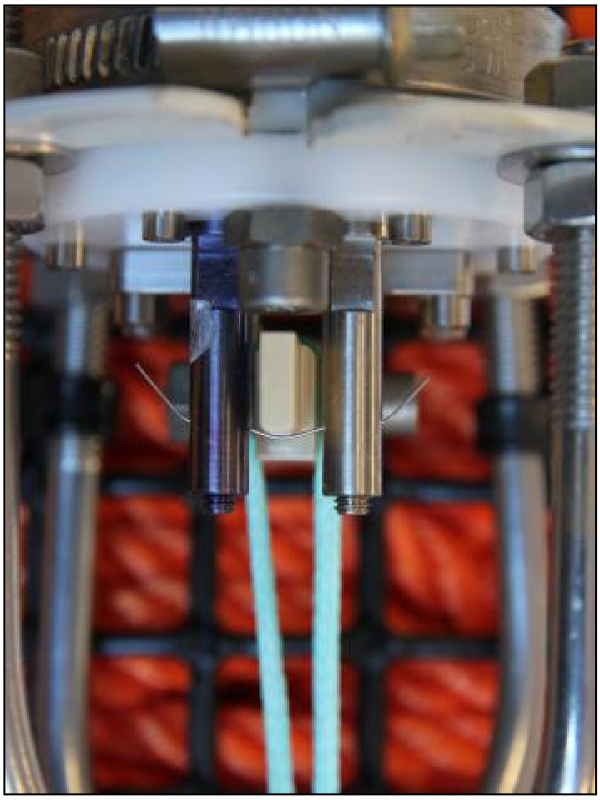


Figure 16. Integration of the ARC-1XDf release unit with a lobster trap.

Figure 17. ARC-1XDf release unit mounted on plastic mesh bag. Release cord runs from the release lever on release unit through stainless steel guides mounted on bag and over the floats and rope contained within the bag (left image) to a "backup" GTR on the opposite side of the bag (right image).

Figure 18. Release lever of ARC-1XDf in closed position (2 views) retaining the release cord. The 26 AWG nickel chromium burn wire can be seen in the image on the right, secured between 2 support posts and holding the release lever closed.





Familiarisation and initial testing of the acoustic release system

Familiarisation with the equipment and initial test deployments and retrievals with the system were done in the controlled environment of a shallow pool. The next phase of test deployments occurred during 3 trips in August and September 2010, aboard a commercial lobster vessel operating out of Botany Bay. During these tests, the gear was deployed in depths ranging from 15 m, inside Botany Bay, to 105 m on the mid-shelf in waters offshore from Botany Bay. During these test deployments a backup line was attached from the trap to a surface buoy to guard against gear loss in the event of problems being encountered.

Further short duration testing and demonstration of the gear was done aboard a second commercial fishing vessel in mid-shelf and outer-shelf depths off Jervis Bay, in September 2011. These tests were to confirm reliable operation of the gear in depths between 220 and 260 m. These depths are greater than the depths at which commercial lobster traps are routinely set in the outer-shelf fishery in NSW.

Mid-shelf 2-month trial with a single trap

Testing then progressed to a 2-month trial using a single trap in 102 m depth off Botany Bay. A backup GTR was deployed in conjunction with the acoustic release to facilitate eventual gear recovery in the event of problems. As a prelude to a larger-scale deep-water trial of the acoustic release system, the objectives of this trial were to confirm the reliability of the gear over 2 consecutive 1-month soaks, observe the amount of biofouling that occurred at this depth and to practice the routine that would subsequently be followed during a larger trial involving multiple traps. The gear was deployed on 22/10/2010 in 1.1 knots of southerly surface current. Gear was successfully retrieved and reset one month later on 22/11/2010. Gear was successfully located and retrieved after an additional month on 21/12/2010.

Shallow water performance trial

A trial of the acoustic release system was done in shallow water to assess (i) the suitability of the system for shallow-water applications and, in particular, (ii) observe the impact of bio-fouling on the reliability of the release system. Two release systems were set on temporary moorings in 18 m depth off Port Hacking on 20/4/2011. Attempts to release the rope and floats to the surface were made after each of 4, 2 – 3 week soaks, a cumulative total soak time of 70 days. One unit was cleaned of biofouling after each lift before being reset. The second unit was not cleaned and allowed to accumulate biofouling. Success or failure in communicating with the release units and successfully releasing floats and ropes was recorded.

Mid-shelf commercial fishing trial-1

An experiment to compare the relative performance of the acoustic release system with a GTR release system, during commercial fishing, was done in mid-shelf depths off Sydney during January – August 2011. Six deep-water lobster traps were set with submerged head-gear using the acoustic release system and 6 were set using GTRs to facilitate release. This experiment ultimately failed due to the implosion of floats within release bags. Further detail regarding this aborted experiment is not presented here. Depth-floats rated to a greater pressure were obtained for subsequent use in a re-run of the experiment (see below).

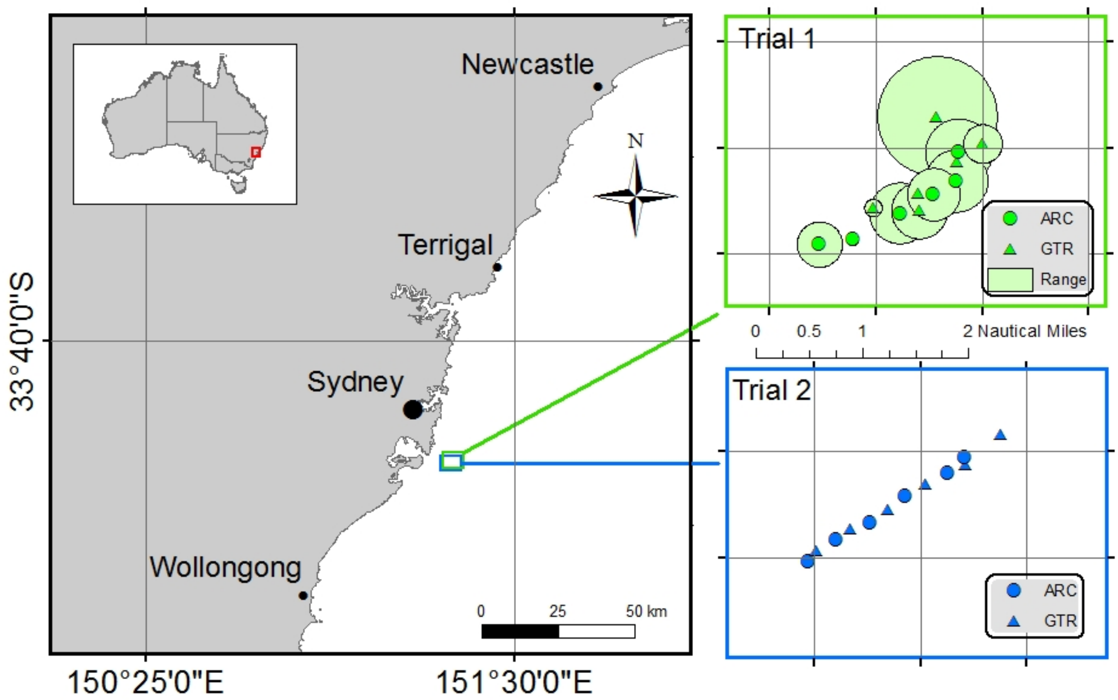
Mid-shelf commercial fishing trial-2

A second, and ultimately successful, experiment to compare the relative performance of the acoustic release system with a GTR release, during commercial fishing, was done in mid-shelf depths off Sydney between December 2011 and June 2012. Six deep-water lobster traps were set with submerged head-gear using the acoustic release system and 6 were set using GTRs to facilitate release. A "backup" GTR was also installed on the release cord of the AR treatment to facilitate the retrieval of traps and acoustic releases in the event of acoustic release failure. Traps were baited and set on 3/12/2011. During the following 6 months, subject to the suitability of weather and ocean currents, attempts were made to retrieve, rebait and reset traps following soaks of approximately 4 weeks. Traps were reset at the same location for each soak.

On each day when trap-lifts were attempted, (i) the presence of absence of GTR-released floats on the surface and (ii) the success or failure to communicate with acoustic release units and effectively release floats to the surface was recorded. The number of lobsters caught in each trap was also recorded. Operational data documenting the performance of the acoustic release system (detected distance from transducer to release unit, battery voltage, stability of communications, command acknowledgments, etc.) were noted. On completion of the experiment, two acoustic release units that failed to function reliably were returned to the manufacturer for diagnosis of the cause of failure.

Evaluation of the relative performance of the acoustic release and GTR systems was based on a comparison of: (i) the number of traps lost during the 6 month fishing period; (ii) mean catch rates per trap-lift for the 2 treatments; and (iii) total catches from AR versus GTR traps.

Figure 19. Location of the mid-shelf trials (the failed Trial-1 and the successful Trial-2) of the acoustic release system during commercial fishing off Sydney.



Results

Initial familiarisation and testing of ARC-1XDf acoustic release system

Design for the system by which the ARC-1XDf was attached to and integrated with a plastic mesh bag for the rope and floats were refined through multiple tests done in a shallow pool.

Multiple deployments and retrievals in depths of 15 m within Botany Bay, 105 m off Botany Bay and depths of 220 m and 260 m off Jervis Bay, confirmed the capability of the system across the range of depths applicable to the deep-water component of the NSW lobster fishery. It was noted throughout these tests that (i) positioning of transducer cable between the STM and transducer away from other electrical equipment in the cabin was necessary to avoid interference "noise"; (ii) it was necessary to turn off the vessels depth sounder (temporarily) when communicating with the release unit to minimise interference "noise" and (iii) initialisation of the acoustic release unit in the deployment bin was most effectively achieved when the vessel was stationary such that movement and noise was minimised.

The acoustic release system performed reliably for all test deployments and retrievals in shallow (15 m) and mid-shelf (105 m) depths. Communications between the surface station and the submerged release units could be established and maintained for separation distances up to 200 – 250 m.

Acoustic releases also functioned reliably for the 2 deployments and retrievals done in 210 m depth off Jervis Bay. At this depth, communications between the surface station and the submerged release unit was established and maintained for separation distances up to 300 – 350 m. A Star-Oddi depth logger was attached to the floats for these tests and revealed that (i) it took just under 7 minutes (6 min. 54 secs. & 6min. 47 sec. for the 2 sets) for the trap and attached released system to sink; and (ii) just over 2 minutes (2 min. 8 sec. & 2 min. 7 sec.) for the floats to rise to the surface after release.

One of the 2 deployments and retrievals in 256 m depth was straightforward. The trap and bag of head-gear took 8 min. 16 sec. to sink and 2 min. 34 sec. to rise to the surface following release. Although the ARC-1XDf release unit performed correctly to release the head-gear following the 2nd set at this depth, the floats did not surface, and the gear was winched back to the vessel using the backup rope. Inspection revealed correct operation of the release unit as the wire had burned, the release latch was open and the release cord was free. The floats, however, remained stuck in the release bag. This represented a problem with the release bag itself and/or packing of the rope and floats into the bag.

Deep-water 2-month trial with a single trap

The gear, a single baited trap with submerged head-gear controlled by an acoustic release, was deployed on 22/10/2010 in 102 m depth off Botany Bay in 1.1 knots of southerly surface current. Gear was successfully located and retrieved 1 month later on 22/11/2010.

Following detection of the release unit, approximately 86 m NNE of the set location, the total time from commencing the release sequence until floats were aboard the vessel was 3 mins 35 secs. No lobsters were caught during this first soak. The trap was re-baited, components of the acoustic release and bag cleaned and repacked with rope, the release system (release cord, burn wire) set up, the release unit initialised and the gear was reset in less than a knot of northerly surface current.

The gear was located and lifted after a further 1-month soak on 21/12/2010, approximately 85 m SSE of the set location. Once communications were established with the release, total time from commencing the release sequence until floats were aboard was 5 minutes. Seventy, lobsters were captured during this soak. The trial concluded.

Minimal biofouling was observed at this depth. With the acoustic release and bag floating approximately 20 m above the trap set in 102 m depth, the release system was approximately 82 m below the surface. Despite surface currents of approximately 1 knot during each set of the gear, the gear was located within 100 m of the set location. After arrival at the set latitude and longitude, communications were established easily with the release unit. Procedures and check-lists worked well. Based on this 2-month trial, involving 2 soak cycles of the gear, there were no contraindications to proceeding with an experiment using multiple traps, with multiple soaks over a longer duration.

Shallow water performance trial

The release unit and bag that was cleaned of biofouling on each lift functioned successfully on each of the 4 set/lift cycles during the experiment. In contrast, the release unit and bag that was not cleaned, accumulated biofouling over the course of the experiment and release of the float from the bag failed on attempts after cumulative soak time of 48 and 70 days (Table 4). On each occasion, the gear was retrieved by grappling. During grappling of the gear after 48 days, the float was released from the bag to the surface. This did not occur during grappling after 70 days cumulative soak time with the float and rope remaining in the bag after retrieval.

Comparison of the 2 gears at the conclusion of the experiment clearly demonstrated the heavy biofouling of gear that was not cleaned during the trial. Biofouling was apparent on the release unit, release cord, bag, rope and float (Fig. 20).

Table 4. Performance of the acoustic release that was cleaned versus the release that was not cleaned of biofouling after each trap-lift during the shallow water trial.

Date	Action	Soak Time (days)	Cumulative Soak Time (days)	Performace & observations	
				Remove Biofouling treatment	*Biofouling* treatment
20/04/2011	Set	0	0	Unit released & float surfaced	Unit released & float surfaced
4/05/2011	Lift / reset	14	14	Unit released & float surfaced	Unit released & float surfaced; increased biofouling
19/05/2011	Lift / reset	15	29	Unit released & float surfaced	Unit released & float surfaced; increased biofouling
7/06/2011	Lift / reset	19	48	Unit released & float surfaced	**FAILURE** - Float not released from bag; gear was grappled and float was released from bag to surface during grappling; confirmation of burnt release unit wire and free movement of release lever
29/06/2011	Lift / Out	22	70	Unit released & float surfaced	**FAILURE** - Float not released from bag; gear was grappled; confirmation of burnt release unit wire and free movement of release lever; heavy biofouling of release cord

Figure 20. Biofouling of the acoustic release and rope/float bags at the conclusion of the shallow water trial.

The bag and release unit on the left was cleaned 22 days prior to the final lift and the unit and bag on the right shows 70 days of accumulated biofouling

Deepwater commercial fishing trial-2

The trial was terminated after 189 days cumulative soak time, at which time 2 remaining GTR traps and 4 AR traps were removed from the water. Two AR traps were subsequently retrieved, after an additional 12 days and 30 days, when the backup GTR had released the head-gear to the surface facilitating retrieval. Thus, on completion of the trial, only 2 of the 6 traps in the GTR treatment had survived 189 days. All 6 traps in the AR treatment survived the course of the trial but in 2 instances this was due to the presence of a backup GTR in the design of the system. A significantly greater proportion of AR traps were retained compared to GTR (AR 6/6, GTR 2/6; $P = 0.0303$, Fishers Exact test, 1-tailed) (Fig. 21).

There was no significant difference in the mean catch rates of lobsters from GTR and AR traps during the first soak (t-test, 2-tailed: $P = 0.373 > 0.05$; Fig. 22). This result confirms that the presence of an acoustic release above a trap did not influence catchability for the trap. Catch rates were not directly comparable for subsequent soaks because soak cycles were no longer in-phase (Fig. 21).

AR traps caught a total of 455 lobsters over the course of the trial, 22% greater than the catch of 373 lobsters from GTR traps. This was unsurprising, given the loss of 2 GTR traps during each of the second and third soaks (Fig. 21).

Successful and unsuccessful releases

There were a total of 18 successful release events during the experiment. A "successful" release was one for which (i) communication was established with the release unit; (ii) a release command was sent to and acknowledged by the unit; (iii) release was confirmed by the unit; and (iv) the released floats were found on the surface within a few minutes and the trap retrieved. There were 6 unsuccessful release events, 3 of which were due to electrical or mechanical faults associated with the release unit. The other 3 unsuccessful events were attributed to failures of the release system (release cord, bag, rope contained within the bag) that resulted in delayed release of floats and rope from the bag and/or arrival of floats at the surface (Fig. 21).

Problems with the release units

Had a backup GTR not been designed into the bag setup for traps in the AR treatment, 3 of the 6 traps would have been lost. Following effective communication with release unit 3130 on day 189 of the experiment and confirmation of release from the unit, the head-gear did not surface. The backup GTR subsequently released the head-gear and the trap was retrieved on day 219 (Fig. 21). Inspection of the release unit revealed that the burn-wire had indeed been burned but the release lever was prevented from opening due to blockage by a tubeworm. Communications could not be established with release unit 3111 (on day 103 or subsequently) or with release unit 2424 (on day 189) and the head-gear was eventually released from the bags by the backup GTRs (Fig. 21) Both release units were returned to and examined by the manufacturer. Release unit 3111 was diagnosed with an electrical fault that resulted in unreliable communications. Release unit 2424 was diagnosed as having excessive draw (above factory acceptable level) on the D-cell battery that powers the circuit board such that the battery ran out of power prematurely after about 5 months. Both units were replaced under warranty.

In summary, 2 of the 6 acoustic release units suffered failures due to internal electrical faults. The need for more stringent quality control procedures was acknowledged by the manufacturer. One of the release units failed due to mechanical blockage by a tubeworm that prevented the release lever from opening. This indicates the need for thorough inspection and de-fouling of the release mechanism prior to each re-set of the gear. Each of these failures illustrates the practical value of including a backup GTR in the system design.

Figure 21. Performance of acoustic releases versus GTRs and associated loss of traps during the mid-shelf commercial fishing trial (trial 2).

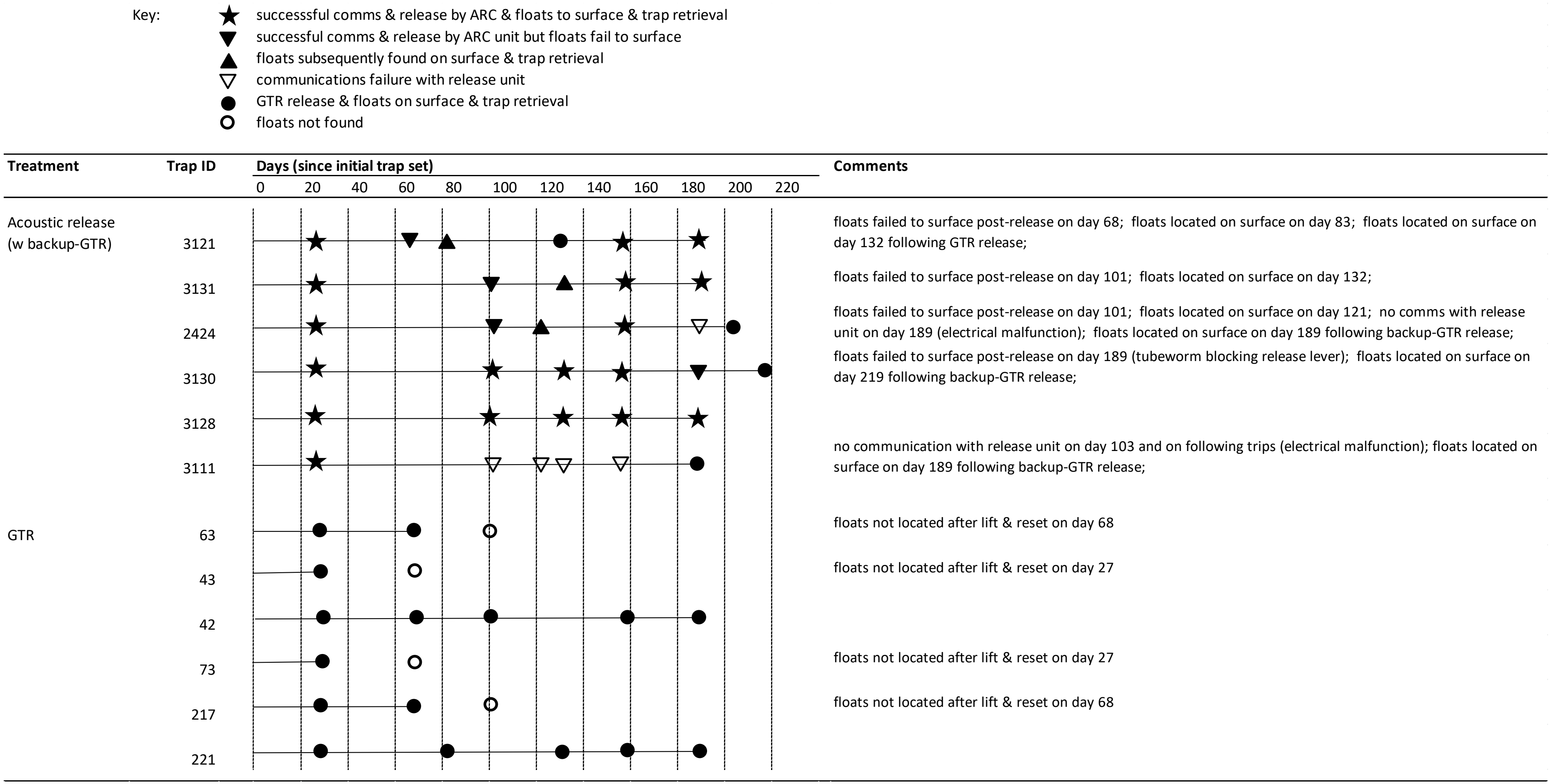
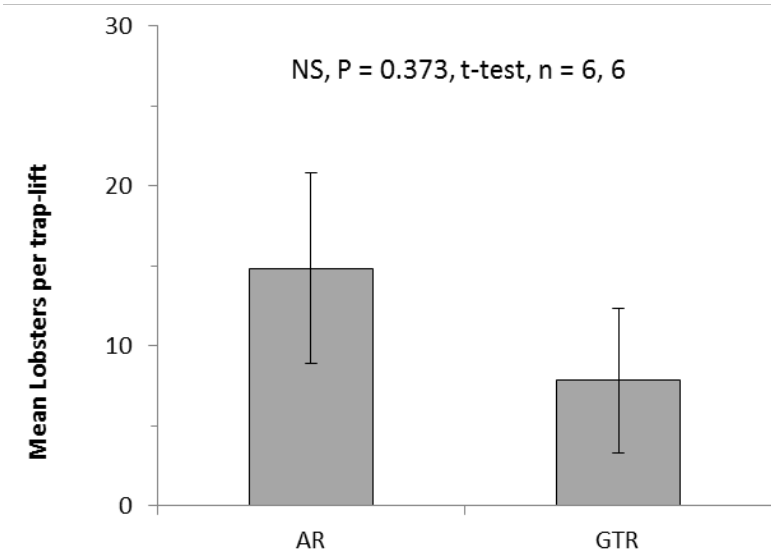


Figure 22. Mean (+/- 1 se) catch rate of lobsters in traps with acoustic release (AR) versus GTR controlled head-gear during the first 21 day soak of the mid-shelf commercial fishing trial (trial 2).



Problems with the release cord, bag or rope within the bag

There were 3 instances during the experiment when communications were established with release units, a release command was sent to and acknowledged by the units, confirmation of release was received from the units, but the floats did not surface. This occurred on day 68 with release unit 3121, on day 101 with release units 3131 and 2424. Floats released by these units were subsequently found on the surface between 15 and 31 days later. These results suggest the failure of the floats to surface immediately was due to some problem with the release bag, release cord or packing of rope and floats within the bag.

Conclusions

The initial testing of the ARC-1XDf acoustic release system and the subsequent 6-month commercial fishing trial off Sydney, provide proof of concept and proof of application with respect to potential use of this system to provide at-call access to submerged head-gear of deep-water lobster traps used in the NSW fishery.

Based on the 6-month commercial fishing trial done in med-shelf depths off Sydney, use of the acoustic release system (incorporating a backup GTR) resulted in no loss of traps, a significantly better outcome compared to traps set using only a GTR. As a consequence, catch of lobsters over the course of the experiment was greater for the traps controlled by acoustic releases.

The presence of acoustic releases on release bags suspended above traps in the water column did not affect catchability of lobsters. Mean catch rates of lobsters per trap-lift did not significantly differ compared to traps set with GTRs.

The use of a backup GTR in conjunction with the acoustic release enabled recovery of traps and acoustic release units in several instances when the acoustic release failed. Routine use of a backup GTR is therefore strongly recommended.

Failures in 2 of the acoustic releases resulted from problems that were subsequently diagnosed by the manufacturer (Desert Star Systems) to be faults in the internal electronics of the units. This indicated the need for more stringent quality assurance and quality control procedures during manufacture and prior to shipping. This conclusion and recommendation was communicated to the manufacturer.

There were 3 instances during the 6-month commercial fishing trial off Sydney and 1 instance when testing the acoustic release system in 256 m depth off Jervis Bay when the acoustic release functioned correctly but the floats and rope did not immediately ascend to the surface. These incidents indicated the need for further refinement of the components of the system other than the release unit itself (design and dimensions of the release bag, rigging of the release unit on the bag, the release cord and guides for the release cord). Fishers that have subsequently purchased the ARC1-XDf acoustic release system have made further refinements as suggested and have experienced fewer instances of delayed release of floats.

Thorough cleaning of the acoustic release, release bag and rigging components following each lift of gear is necessary to minimise the chance of subsequent release failures. This was evidenced by the trial of the system in shallow water during which biofouling accumulated quickly and the single incident during the 6-month commercial fishing trial when the release lever of one of the units was prevented from opening due to blockage by a tubeworm.

General conclusions, implications and recommendations

Based on the experiments that simulated ghost fishing at both Jervis Bay and Seal Rocks, ghost fishing will occur when deep-water lobster traps fished in mid-shelf and outer-shelf depths off the coast of NSW are lost. Lost traps will continue to catch and accumulate lobsters until the structural integrity of the trap is compromised after approximately 14 months.

The mortality of lobsters resulting from ghost fishing is difficult to determine. As a proportion of the number of lobsters that entered the traps during the simulated ghost fishing, the vast majority were still resident in traps prior to trap breakdown. The condition of these lobsters was, however, compromised by long term residency. Weight at length and a qualitative index of vigour, deteriorated over time (significant differences detected after 9 months residency) during the experiments at both Jervis Bay and Seal Rocks. It is unclear what subsequent mortality such long-term resident lobsters would experience following escape after breakdown of the trap.

Despite uncertainty about the actual mortality resulting from lost traps and ghost fishing, it is clearly desirable to minimise the potential mortality. Sacrificial panels, that corrode and breakdown more quickly than the rest of the trap, were potentially a means to facilitate escape of lobsters from traps that were lost and ghost fishing. The experiments done during this project considered the utility of the trap door as a sacrificial panel. These experiments applied 3 levels of cathodic protection to the wire in the trap door (no sacrificial anode, 10 cm anode, 20 cm anode). Whilst the panels with least protection from corrosion (no anode) did corrode and break down more quickly than those with 10cm or 20cm anodes, there was substantial variation in the amount of time required for breakdown to occur among locations. This varied between approximately 6 months for the experiments done at locations off Jervis Bay and Port Macquarie and 12 months at a location off Terrigal. Moreover, fishers have reported that they observe differences in rates of corrosion of their traps set at different sites they routinely fish from their home ports. This suggests variation in rates of corrosion and breakdown time at a much finer spatial scale than that considered in the experiment. The experiments did not reveal correlations between latitude or water temperature with breakdown time for the panels. Traps at the location at which sacrificial panels had the greatest longevity (Terrigal) caught significantly lesser quantities of lobsters and hermit crabs and this suggests the possibility that physical abrasion of panel wire by resident lobsters and hermit crabs may influence corrosion and breakdown time. The main factors responsible for the observed differences in breakdown time of sacrificial panels among the 3 locations remain unclear.

Whilst the breakdown of sacrificial panels did facilitate the escape of resident lobsters, the substantial variation in the speed of corrosion and consequent breakdown time of sacrificial panels among locations severely limits the potential for implementing a standard design of sacrificial panel across the fishery. Further investigation and understanding of factors affecting corrosion and breakdown time and associated spatial and temporal variation is unlikely to alter this conclusion.

The use of acoustic releases to facilitate at-call access to the head-gear of traps offers a potential solution to the loss of traps and consequent ghost fishing. The initial testing of the ARC-1XDf acoustic release system and the subsequent 6-month commercial fishing trial off Sydney, provide proof of concept and proof of application with respect to potential use of this system by fishers in the NSW fishery. Based on the 6-month commercial fishing trial done in mid-shelf depths off Sydney, use of the acoustic release system (incorporating a backup GTR) resulted in no loss of traps, a significantly better outcome compared to traps set using only a GTR. As a consequence, catch of lobsters over the course of the experiment was greater for the traps controlled by acoustic releases.

The use of a backup GTR in conjunction with the acoustic release enabled recovery of traps and acoustic release units in several instances when the acoustic release failed. Failures in 2 of the acoustic releases due to malfunction of electronics within the units indicated shortcomings with the quality assurance and quality control procedures used by the manufacturer at the time of purchase. This conclusion and the obvious recommendation to implement more stringent quality control and assurance protocols were communicated to the manufacturer.

Further modifications and refinement of the components of the release system, other than the release unit itself, were also deemed necessary. There were several instances when the acoustic release functioned correctly but floats and rope failed to ascend to the surface. Experimenting with the design and dimensions of the release bag, rigging of the release unit on the bag, the release cord and guides for the release cord to reduce delays in the release of floats to the surface was recommended. Fishers that have subsequently purchased the ARC1-XDf acoustic release system have indeed made further refinements as suggested and have experienced fewer instances of delayed release of floats.

A further recommendation made to fishers who have subsequently purchased the ARC1-XDf system concerned the importance of thorough cleaning of the acoustic release, release bag and rigging components following each lift of gear to minimise the chance of subsequent release failures. Biofouling was found to be significant and a potential problem during trials of the gear in shallow water. Even though biofouling did not occur to the same extent with the release units set in deeper offshore waters, there was one instance when the release lever on the release unit was prevented from opening due to the presence of a tubeworm.

Two of the fishing business that assisted with this project, having observed the system in use on their vessels, immediately purchased the ARC-1XDf system for installation on their vessels. It was their commitment to purchase of the system that prompted a subsequent application to FRDC for a specific industry extension project (see Extension and Adoption re FRDC project no. 2012/504).

Both businesses that subsequently purchased the system possessed the attributes that were compatible with the potential cost-effective use of the system:

(i) large shareholdings and therefore large annual quotas;

(ii) high catch rates of lobsters per trap-lift during peak season such that an acoustic release costing $2,000 was protecting the contents of a trap containing up to $10,000 worth of lobster;

(iii) frequent exposure to cut-offs of head-gear on the surface by commercial shipping and trawlers;

(iv) recognition of health, safety and lifestyle benefits that would result from not feeling compelled to go to sea and lift traps when the floats had surfaced following release by a GTR.

Further development

An important outcome from this project was the proof of concept and proof of application with respect to the use of the ARC-1XDf acoustic release system to provide at-call access to submerged head-gear. Two of the fishing business that assisted with this project, having observed the system in use on their vessels, immediately purchased the ARC-1XDf system for installation on their vessels. It was their commitment to purchase of the system that prompted a subsequent industry-extension project "*Industry-extension of acoustic release technology for at-call access to submerged head-gear in the NSW rock lobster fishery"* (FRDC project no. 2012/504). This project concerned the first stages of extending acoustic release into the NSW lobster fishery. Since 2013-14, the early adopters of this technology have hosted other NSW lobster fishers aboard their vessels to demonstrate application of the system. An additional fishing business, based on the north coast of NSW, has since invested in the acoustic release system. This further phase in extension has been one mediated within the fishing industry, with experienced practitioners (the Jervis Bay fishing business) essentially mentoring another fisher with respect to practices and strategies for using the system efficiently.

The cost of the acoustic release system has however, proven to be a significant barrier to the purchase and adoption of the system by other fishers operating in the deep-water component of the fishery. These fishers continue to use GTRs or alternative approaches to submerse the head-gear of their deep-water traps. In contrast to the use of acoustic releases, the GTR technology results in submersion of the head-gear for less than 100% of the soak-time of traps. Nevertheless, the likelihood of trap loss due to cut-off of ropes and floats on the surface following GTR release is significantly reduced compared to conventional surface-set head-gear. Several fishers have effectively dispensed with the use of head-gear altogether by setting their traps with a horizontal line to a weight or anchor. A depth-float on the horizontal line between the trap and anchor facilitates grappling of the gear.

Extension and Adoption

This project prompted a successful application to FRDC for funding from the tactical research fund for the project "*Industry-extension of acoustic release technology for at-call access to submerged head-gear in the NSW rock lobster fishery"* (FRDC project no. 2012/504). Objectives of this project concerned: installation of the ARC1-XDf acoustic release system and integration with on-board electronics on several vessels operating in the NSW lobster fishery and provision of initial training and support for the effective use of the system. Under this project, fishers had to purchase the acoustic release system at their own cost. The acoustic release system has since been purchased and successfully adopted by several fishing business operating in the NSW lobster fishery.

Appendices

Researchers, project staff, fishers/skippers & consultants

Dr Geoffrey Liggins, Scientist, NSW Department of Primary Industries

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Mr Scott Westley and Mr Mal Gorry, Lobster shareholders and fishers, Huskisson

Mr Noel Gogerly and Mr Daniel Gogerly, Lobster shareholders and fishers, Forster/Tuncurry.

Mr Peter Offner and Mr Mark Cranstone, Lobster shareholders and fishers, Broken Bay

Mr Steven Burt, Lobster shareholder and fisher, Port Macquarie

Mr Marco Flagg, Electrical engineer, Desert Start Systems (USA)

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