USING A VIDEO CAMCORDER TO QUANTIFY SPATIAL ASSOCIATION BETWEEN SEABIRDS AND THEIR PREY

RICHARD R. VEIT,[1] JARROD A. SANTORA[1] & HAROLD OWEN[2]

[1]Biology Department, CSI/CUNY, 2800 Victory Boulevard, Staten Island, New York, 10314, USA
(veitrr2003@yahoo.com)
[2]Raytheon Polar Services Co., 7400 South Tucson Way, Centennial, Colorado, 80112-3938, USA

Received 24 May 2007, accepted 16 June 2008

SUMMARY

VEIT, R.R., SANTORA, J.A. & OWEN, H. 2008. Using a video camcorder to quantify spatial association between seabirds and their prey. *Marine Ornithology* 36: 145–151.

Studies of marine predators that feed on krill and other plankton are often hampered by the difficulty of continuously sampling prey within the uppermost layers of the water column. Echo sounders, whether hull-mounted or towed, usually “miss” the uppermost two meters or so of the ocean’s surface. Many non-diving seabirds, such as petrels and albatrosses, can access only krill and other prey that are located within the uppermost two meters. Therefore, a clear need exists to sample plankton abundance at the ocean’s surface. We used a video camcorder to do this, aboard the National Science Foundation’s R/V *Laurence M. Gould* near Elephant Island in the Antarctic Peninsula during December 2003. We towed the camcorder on a cable that also supported a towed echo-sounding transducer. In the present paper, we compare plankton abundance estimated by echo sounder and camcorder simultaneously, and we correlate these two measures of plankton abundance with visual estimates of bird abundance and quantification of bird behavior. We ask whether (1) krill could be detected using video technology; (2) krill estimated by echo sounder could be corroborated by camcorder; (3) krill detected at the surface by camcorder had predatory birds associated with it. Our analysis shows that camcorder and echo sounder ought to be used simultaneously to sample seabird prey. The camcorder most faithfully records prey for surface-feeding birds, but acoustic methods are more suitable for sampling the prey of diving birds, especially penguins.

Key words: Seabird–prey interactions, video camcorder, acoustic plankton sampling, Antarctica, foraging behavior

INTRODUCTION

Pelagic seabirds and their prey, despite their occupancy of habitats remote to most humans, provide a surprisingly convenient system in which to study interactions between predators and prey because of the relative ease with which the spatial distributions of these animals can be measured (Hunt & Schneider 1987). Seabirds at sea are easily seen and identified, and their prey can be continuously measured using either acoustics or continuous plankton recorders (Aebischer *et al.* 1990). Echo sounders have proven especially useful for quantifying the spatial distribution of plankton and fish (Everson & Bone 1986, Weber *et al.* 1986, Greene *et al.* 1989, Wiebe *et al.* 1990, Hewitt & Demer 1993, Demer & Hewitt 1995) because they can be towed alongside a ship from which observations of birds are being made and because they have the ability to detect objects within the size range of krill and small fishes.

Echo-sounding transducers typically are either mounted in the ship’s keel or encased in a hydrodynamically contoured housing and towed alongside. Either type of transducer can be towed at speeds of 5–15 kn (approximately 8–20 km/h). Keel-mounted transducers broadcast from keel depth; towed transducers usually are towed 2–5 m below the ocean surface. Because of the potential for interference between outgoing and incoming signals, objects directly in front of the transducer often cannot be resolved (Foote *et al.* 1987). The effective sampling range of echo sounders therefore begins at a minimum of 2 m beneath the ocean surface, and with some keel-mounted transducers, any object shallower than about 7 m cannot be resolved.

Seabird ecologists often need to measure the degree of spatial correlation between seabirds and their prey, and to identify at which spatial scale such correlation occurs (Schneider & Piatt 1986, Piatt 1990, Rose & Leggett 1990, Hunt *et al.* 1992, Veit *et al.* 1993). Because many seabirds cannot dive deeper than 1–2 m (Murphy 1936, del Hoyo *et al.* 1992, Warham 1996), it is of critical importance to measure the prey available in the uppermost layers (1–2 m) of the water column.

We used a video camcorder to make those measurements. We mounted a video camcorder inside a homemade waterproof casing and lowered the camcorder on a cable that supported a towed echo-sounding transducer. The echo sounder and camcorder were towed alongside the starboard quarter of the research vessel at 3–5 kn (approximately 6–8 km/h). During towing time, we counted and recorded the behavior of birds from the ship’s pilothouse. In the present paper, we show that the simultaneous use of camcorder and echo sounder provide an effective tool for quantifying plankton prey available to surface-feeding seabirds.

METHODS

Field methods

Data were collected in the vicinity of Elephant Island (61°S, 55°W), during 15/16 December 2003, on board the National Science Foundation research vessel *Laurence M. Gould.* Sampled transects were located northeast of Elephant Island on the insular shelf. For each transect (n = 7), we collected one-minute samples of

- acoustic estimates of krill abundance,
- video estimates of krill abundance, and
- visual estimates of bird abundance.

At 4 kn, each one-minute bin corresponded to about 100 m of linear transect.

The *Laurence M. Gould* is equipped with a towed echo sounder (Split Beam Model DES244: HTI Hydroacoustic Technology, Seattle, WA, USA), which transmits at two frequencies: 120 KHz and 38 KHz with a 6-degree beam angle and 2 pps. The echo-sounding transducer is mounted in an aluminum frame ("fish" hereafter, Fig. 1), suspended from a "knuckle" crane and towed alongside the starboard side of the ship. The fish was towed about 2 m beneath the ocean surface. Acoustic data on krill abundance were integrated over 10-m depth intervals, and back-scattering strength was summed from 3–50 m beneath the surface.

We mounted a Sony DCR-TRV 50 video camcorder inside a waterproof housing attached to the fish [Fig. 2(a,b)]. The housing was made from a length of 6" diameter PVC tubing, closed at the rear end with a circular section of PVC and at the front end with a circular section of plexiglass, both seated on rubber gaskets and secured by stainless steel screws (Fig. 2). The camcorder operated on its own rechargeable battery. In water approximately 0.0°C, the battery lasted for at least 60 minutes, the length of our recording tapes. We pulled the fish out of the water every hour to change battery and tape. We then estimated plankton abundance visually from the tapes (see video appendix, and scored each one-minute segment on a linear scale between zero and 100, based on number of plankters present.

Birds were counted within 300 m to the starboard side of the ship (Tasker *et al.* 1984, Veit *et al.* 1993) from the pilothouse (10 m above the water). We identified all birds to species and recorded each bird's or flock's behavior as flying, sitting or feeding. Data on birds were recorded using the Dlog software package (R.G. Ford Consulting, Portland, OR, USA), which assigned a time (nearest second) and spatial position (latitude and longitude to nearest minute) to each record.

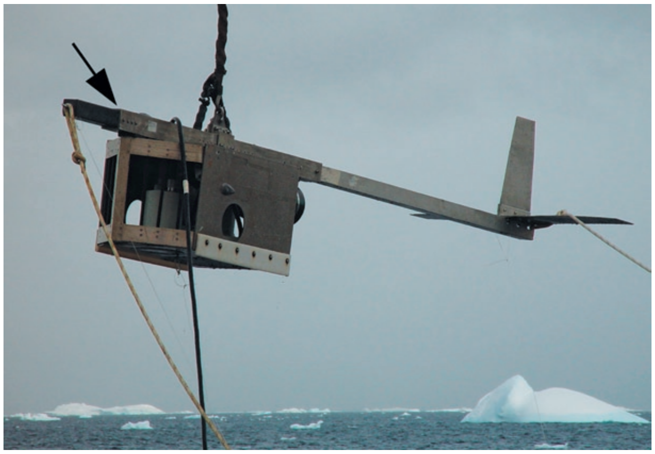

Fig. 1. The towed "Fish" ready for deployment. The arrow indicates where the camcorder was mounted.

Table 1 shows the data accumulated on each transect.

Analytical methods

Our raw data consisted of linear arrays of one-minute bins of data on bird and plankton abundance. Two variables were recorded for plankton, one for the acoustic estimate and another for the video-based estimate. Data on birds were grouped into categories for species and behavior. We focused on four species: Chinstrap Penguin *Pygoscelis antarctica,* Cape Petrel *Daption capense,* and the species pair Wilson's Storm-Petrel *Oceanites oceanicus* and Black-bellied Storm-Petrel *Fregetta tropica* (hereafter grouped

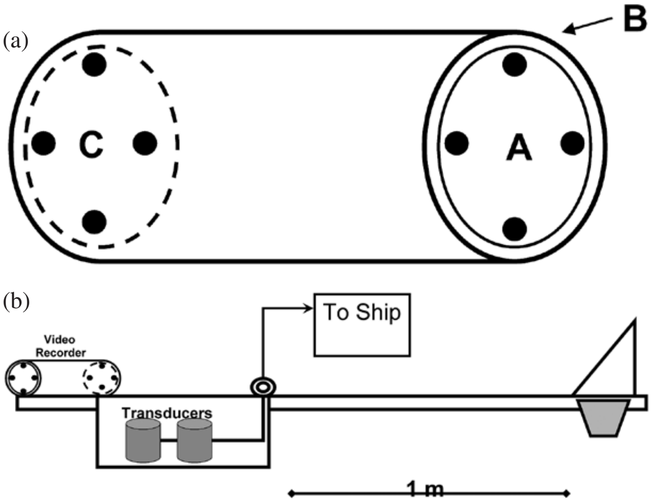

Fig. 2. (a) Underwater video camera case. The case was constructed from a polyvinylchloride tube seven inches in diameter. A is the window where the camera lens was oriented; B is a sheet of 0.5-inch Plexiglas adhered to the tube with waterproof silicone; C is the rear of the case, where the camera was inserted. The dashed oval indicates the waterproof gasket, which was fixed to the case, and an additional piece of Plexiglas. Filled circles indicate the locations of screws. (b) Attachment of camcorder to towed "fish." The fish consists of aluminum struts with fins for stabilization and a casing to hold the transducers. It is towed from the side of the ship on a cable suspended from a J-crane.

TABLE 1
Cape Petrels *Daption capense* and krill from seven transects

Transect[a]	Cape Petrels		Acoustic	Camcorder
	Total	Feeding	krill	krill
0840	50	1	0.00044	12
1003	163	16	0.00043	34
1124	65	33	0.00039	134
1245	46	5	0.00024	31
1408	41	5	0.00015	3
0916	158	8	0.00013	4
1035	93	1	0.00006	13

[a] Transects are identified by starting time.

together as "storm-petrels"). We then partitioned the Cape Petrels into groups of feeding, flying and sitting birds. We did not partition either the penguins or the storm-petrels because it was much more difficult to ascertain when these birds were feeding.

We first measured the correlation between acoustic and video-based measures of krill abundance. Second, we measured the correlation between seabirds and plankton. The correlation analyses used four variables: acoustically detected krill, video-detected krill, total bird abundance and feeding bird abundance. We used the Statistica software package (StatSoft, Tulsa, OK, USA) to calculate cross-correlations between series. Statistica uses Pearson correlation coefficients and deems those associated with $p < 0.05$ to be statistically significant (indicated by a dashed line on the illustrations in this paper). We checked these parametric correlations with nonparametric Spearman correlation coefficients for bias because of the non-normality of the data.

RESULTS

The camcorder clearly resolved individual krill and other similarly-sized plankton, and also effectively resolved swarms of krill. A section of the footage obtained can be viewed online (Veit *et al.* 2008). The image shows one of the larger krill swarms detected with the camcorder, on transect 1124 on 15 December 2003.

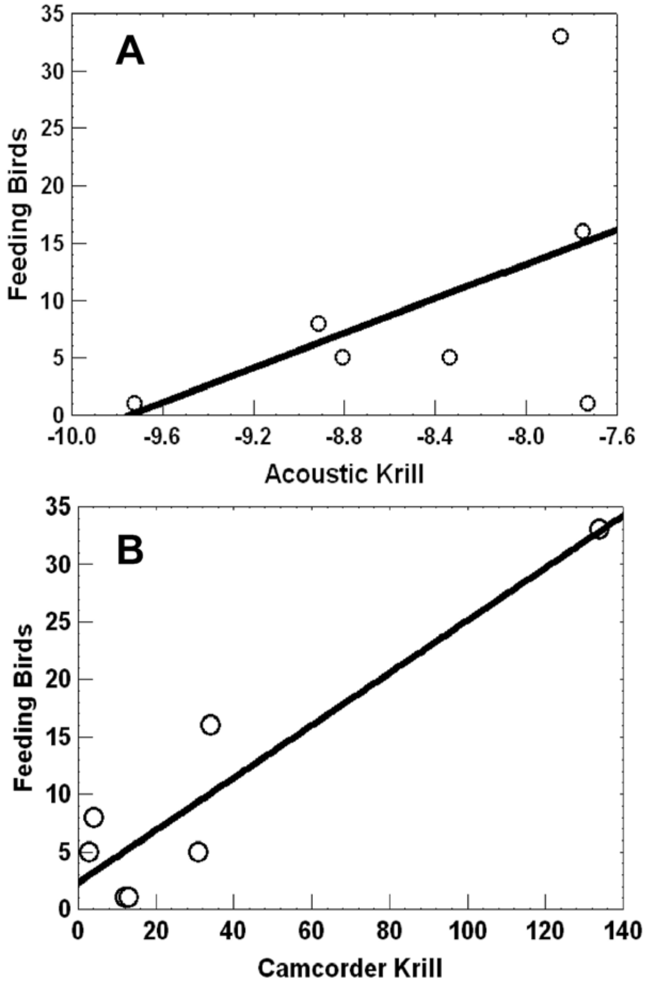

Fig. 3. Correlation at the transect scale between feeding Cape Petrels *Daption capense* and krill measured by (A) acoustics and (B) camcorder.

Transect-scale analyses

To begin assessing the usefulness of the camcorder for detecting krill swarms, we calculated the correlation between bird and krill abundance at the scale of the individual transects, which were each about 10 km long.

For Cape Petrels, the correlation between number of feeding birds seen on a transect and the krill detected by camcorder was remarkably strong [$r_p = 0.92$, $P < 0.005$, $n = 7$; Fig. 3(a,b)] and about twice (with r^2 values three times) the correlation between the number of feeding birds and acoustically detected krill ($r_p = 0.48$, $0.5 > p > 0.2$, $n = 7$). Using "total Cape Petrels" counted rather than just feeding birds, the relationships were much weaker. The correlation between total birds and krill detected by camcorder ($r_p = 0.14$, $p > 0.5$) was still stronger than that between total birds and acoustically detected krill ($r_p = 0.01$, $p > 0.5$).

For Chinstrap Penguins and storm-petrels, we observed no significant correlation between birds and krill at the scale of entire transects (10 km).

The correlation between video-based and acoustic-based krill at this scale was positive, but not significant ($r = 0.47$, $P = 0.27$, $n = 7$).

Fine-scale analyses

For Cape Petrels we used four analyses to assess correspondence between birds and krill, based on two methods of plankton sampling (acoustic and video) and two measures of bird abundance ("total birds" and "feeding birds"). For Chinstrap Penguins and storm-petrels, we did not distinguish between feeding and non-feeding birds, and so we used only total birds for these species. We used cross-correlation to measure correspondence between birds and plankton along the 10-km transects. Fig. 4(c–f) shows an example of the raw data from transect 1124. The sampling intervals were one minute of transect or about 100 m at 5 kn. We measured cross-correlation out to lags of ±15 minutes or 1500 m. We considered a correlation between birds and plankton to be biologically meaningful if it occurred within a lag of ±5 minutes.

On two of the seven transects (1124 and 1408), we observed significant cross-correlation between video-detected and acoustic-detected krill.

For feeding Cape Petrels and acoustically detected krill, we observed significant cross-correlation on five of seven transects (Table 2). For feeding Cape Petrels and camcorder-detected krill, we observed significant cross-correlation on three of seven transects [Figs.4(b), 5(b), 6(b)]. The acoustics and camcorder "agreed" on two of the transects (1124 and 1245); three were identified by acoustics only, and one was identified by camcorder only (Table 2). For "total Cape Petrels" and acoustically-detected krill, we observed significant cross-correlation on one of seven transects (1035). For "total Cape Petrels" and camcorder-detected krill, we observed a significant correlation on three of seven transects. These transects included 1124 (that was identified by both methods using feeding birds), 0916 and 1035.

Thus, for Cape Petrels, the acoustic transducer and the camcorder both detected seabird-relevant patches of krill that were not detected by the other instrument.

The comparison between surface-feeding storm-petrels and diving penguins at the one-minute scale were especially revealing.

For storm-petrels, five of seven transects yielded a significant association between birds and video-based krill. However, two of seven showed an association based on acoustics (Table 3, Fig. 7). For penguins, on the other hand, four of seven transects showed a significant association using acoustic-based krill, but only one of seven transects showed an association using video-based krill. Thus, the camcorder usefully recorded prey important to surface-feeding birds, and the acoustics were more useful for finding prey of diving birds.

DISCUSSION

This analysis of data collected simultaneously by camcorder and acoustics shows that such a combined array is feasible, even in the challenging environment of the Antarctic. More importantly, our analysis suggests that both these instruments ought to be used in future studies of seabirds and their prey so as to ensure adequate resolution of the water column. Some patches important to birds were detected by camcorder but not by echo sounder, and vice versa.

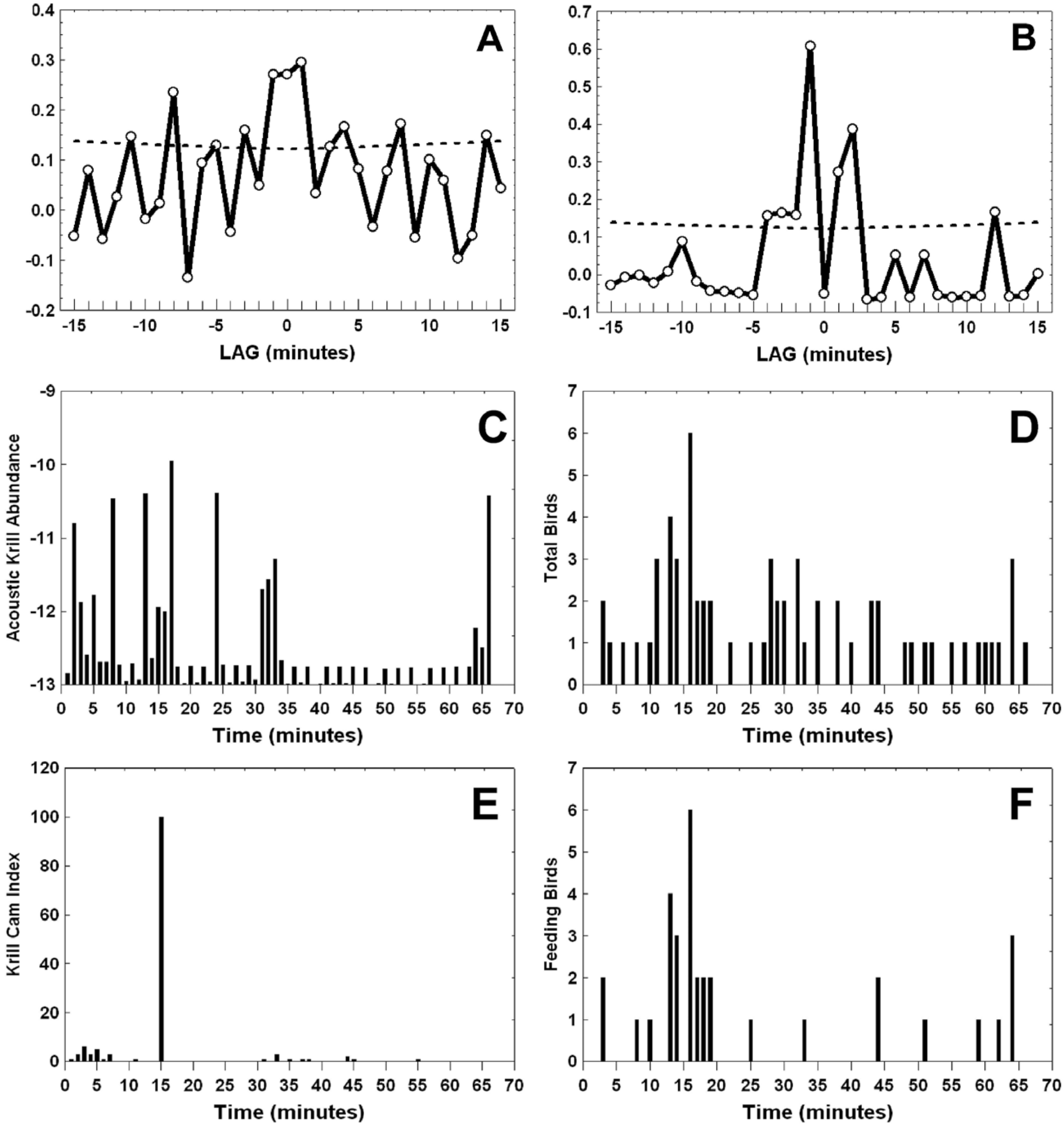

Fig. 4. Cross-correlations between feeding Cape Petrels *Daption capense* and (A) acoustically determined krill and (B) camcorder-detected krill on transect 1124. Distribution of (C) acoustic krill, (D) total birds, (E) camcorder krill, and (F) feeding Cape Petrels along transect 1124.

Furthermore, our data clearly show that the camcorder is better at detecting prey at the surface and that the acoustics are better at detecting prey at depth, justifying the simultaneous deployment of both instruments. Given evidence of mutualistic search strategies between penguins and flying birds (Harrison *et al.* 1991, Grünbaum & Veit 2003), detecting prey for all birds simultaneously will be necessary for understanding the formation of feeding flocks and processes underlying spatial distributions of seabirds. In addition, the echo sounder samples a much larger total area of the water column; the camcorder detects plankton only within a small window immediately in front of the lens.

Our main concern in conducting this study was to detect whether various methods used in the past have failed for one reason or another to detect plankton in the water column. We could not test this question directly, because we had no independent measure of the plankton that were present. But we did have three different sampling devices: birds, camcorder and echo sounder. We were most interested in whether prey patches located by birds were undetected by either of our prey-sampling devices. Using our threshold values for patches, there appeared to be only one occasion on which a miss seems to have happened: transect 0916. On that transect, one group of three birds and a second group of two birds were feeding immediately adjacent to one another, for which neither camcorder nor acoustics determined that plankton was associated. Three other patches were detected by acoustics but missed by the camcorder, and no patches found by birds were detected by camcorder alone. The nine other aggregations of more than three birds feeding together were all detected by either camcorder or echo sounder.

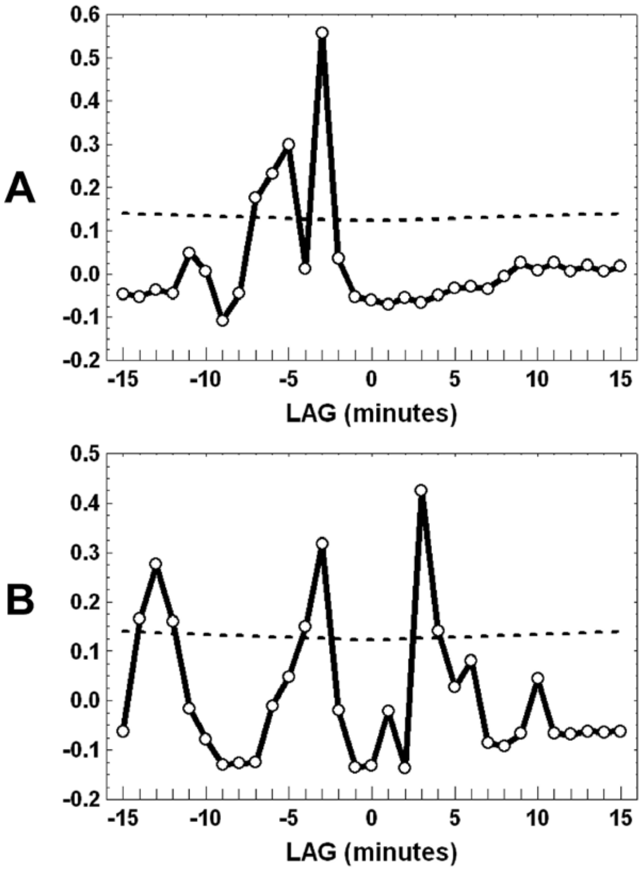

Fig. 5. Cross-correlations between feeding Cape Petrels *Daption capense* and (A) acoustically determined krill and (B) camcorder detected krill on transect 1245.

Previous studies of spatial association between birds and prey (McClatchie *et al.* 1989, Hunt *et al.* 1992, Veit *et al.* 1993) have commonly revealed low correlation between birds and prey. Part of the reason for this low correlation is the difficulty marine predators have in finding prey, such that many prey patches may remain undetected. Another reason is that interactions between seabirds and prey are short-lived and therefore missed by ship-based sampling schemes (Veit *et al.* 1993). However, some cases of low correlations

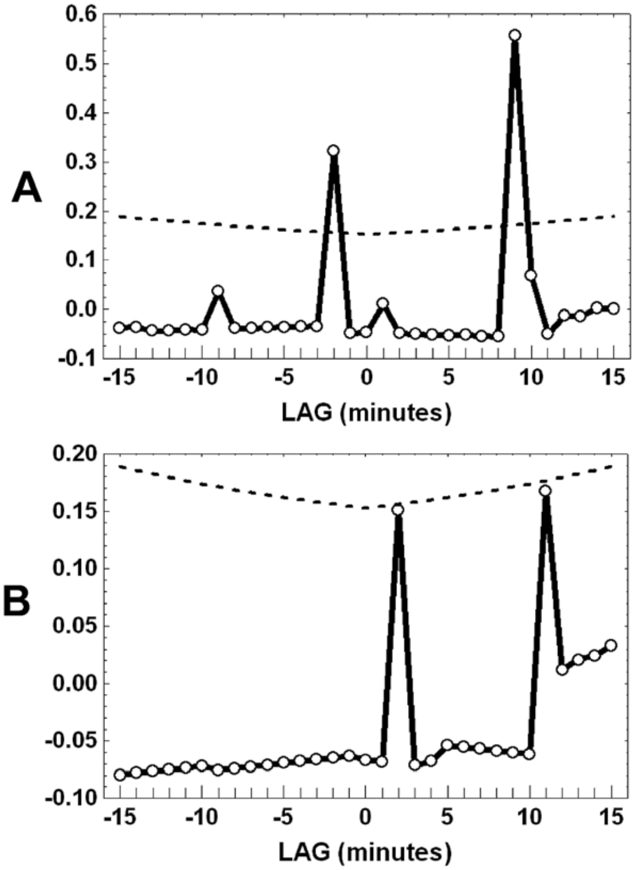

Fig. 6. Cross-correlations between feeding Cape Petrels *Daption capense* and (A) acoustically determined krill and (B) camcorder detected krill on transect 1035.

TABLE 2
Fine-scale association between Cape Petrels *Daption capense* and krill

Transect[a]	Feeding Cape Petrels		Total Cape Petrels	
	Camcorder	Acoustics	Camcorder	Acoustics
0840	Yes	No	No	No
1003	No	Yes	No	No
1124	Yes	Yes	Yes	No
1245	Yes	Yes	No	No
1408	No	No	No	No
0916	No	Yes	Yes	No
1035	No	Yes	Yes	Yes

[a] Transects are identified by starting time.

TABLE 3
Fine-scale association between Chinstrap Penguins *Pygoscelis antarcticus*, storm-petrels and krill

Transect[a]	Chinstrap Penguin		Storm-petrels	
	Acoustics	Camcorder	Acoustics	Camcorder
0840	Yes	No	Yes	No
1003	Yes	No	No	Yes
1124	Yes	No	Yes	Yes
1245	No	No	No	Yes
1408	No	No	No	Yes
0916	Yes	Yes	No	No
1035	Yes	Yes	No	Yes

[a] Transects are identified by starting time.

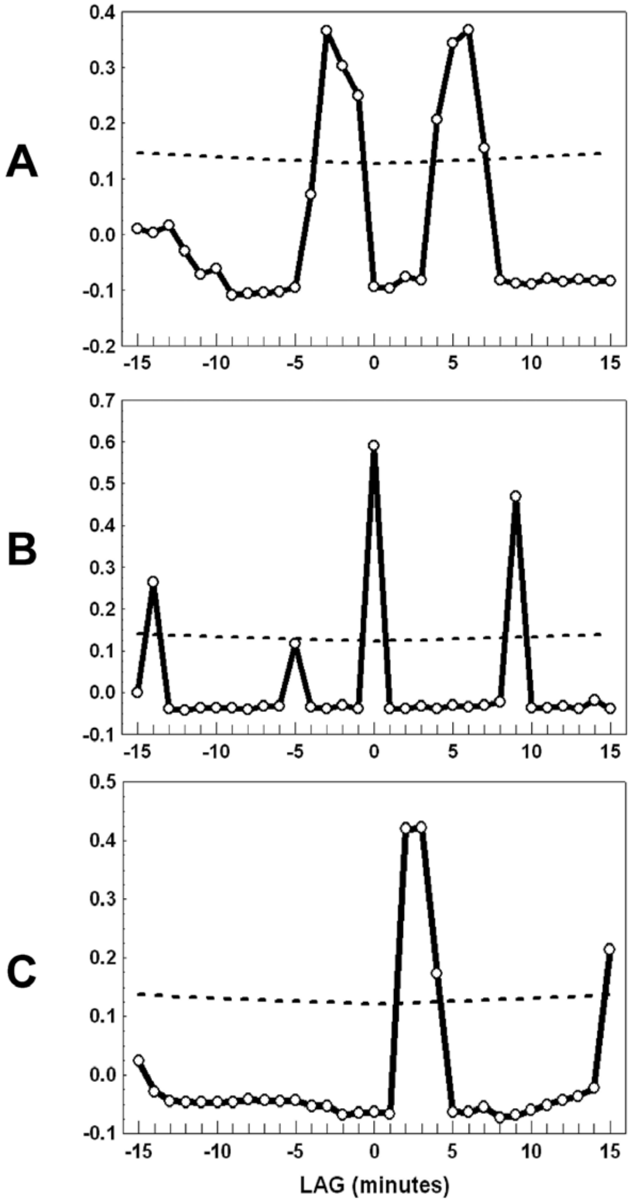

Fig. 7. Cross-correlations between seabird and krill: (A,B) Chinstrap Penguin *Pygoscelis antarcticus* and acoustically determined krill on transects 0840 and 1003. (C) Cross-correlation between camcorder detected krill and storm-petrels on transect 1124.

may have been caused by the resolution of instruments used to detect prey underwater. In this study, we clarify two issues:

- Video camcorders are effective at detecting surface zooplankton that are invisible to echo sounders.
- Acoustics are nevertheless needed to detect zooplankton at depths that are important to diving birds

Hence, future studies of seabirds and their prey should use camcorders and acoustics together to sample prey available to seabirds. We have demonstrated the feasibility of doing so.

ACKNOWLEDGEMENTS

Evelyn Neunteufel helped to assemble and deploy the camcorder. Sasha Auer, Tom Brown, Marie-Caroline Martin and Malin Pinsky collected data on birds. We thank the officers and crew of the R/V *Laurence M. Gould* for their skillful assistance. This project was supported by NSF grant OPP9983751 to RRV.

REFERENCES

AEBISCHER, N.J., COULSON, J.C. & COLEBROOK, J.M. 1990. Parallel long-term trends across four marine trophic levels and weather. *Nature* 347: 753–755.

DEMER, D.A. & HEWITT, R.E. 1995. Bias in acoustic biomass estimates of *Euphausia superba* due to diel vertical migration. *Deep-Sea Research Part I* 42: 455–475.

EVERSON, I. & BONE, D.G. 1986. Effectiveness of the RMT8 system for sampling krill (*Euphausia superba*) swarms. *Polar Biology* 6: 83–90.

FOOTE, K.G., KNUDSEN, H.P., VESTNES, G., MACLENNAN, D.N. & SIMMONDS, E.J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. *ICES Cooperative Research Report* 144: 1–69.

GREENE, C.H., WIEBE, P.H. & BURCZYNSKI, J. 1989. Analyzing distribution of zooplankton and micronekton using high frequency, dual-beam acoustics. *Progress in Fisheries Acoustics* 11: 45–54.

GRÜNBAUM, D. & VEIT, R.R. 2003. Black-browed Albatross foraging on Antarctic krill: density-dependence through local enhancement? *Ecology* 84: 3265–3275.

HARRISON, N.M., WHITEHOUSE, M.J., HEINEMANN, D., PRINCE, P.A., HUNT, G.L. Jr & VEIT, R.R. 1991. Observations of multispecies seabird flocks around South Georgia. *Auk* 108: 801–810.

DEL HOYO, J., ELLIOTT, A. & SARGATAL, J. 1992. Handbook of birds of the world. Vol. 1. Barcelona: Lynx Editions. 696 pp.

HEWITT, R.E. & DEMER, D.A. 1993. Dispersion and abundance of Antarctic krill in the vicinity of Elephant Island in the 1992 austral summer. *Marine Ecology Progress Series* 99: 29–39.

HUNT, G.L. Jr, HEINEMANN, D. & EVERSON, I. 1992. Distributions and predator-prey interactions of Macaroni Penguins, Antarctic Fur Seals and Antarctic krill near Bird Island, South Georgia. *Marine Ecology Progress Series* 86: 15–30.

HUNT, G.L. & SCHNEIDER, D.C. 1987. Scale-dependent processes in the physical and biological environment of marine birds. In: Croxall, J.P. (Ed). Seabirds: feeding ecology and role in marine ecosystems. Cambridge, UK: Cambridge University Press. pp. 7–41.

MCCLATCHIE, S., HUTCHINSON, D. & NORDIN, K. 1989. Aggregation of avian predators and zooplankton prey in Otago shelf waters. *New Zealand Journal of Plankton Research* 11: 361–374.

MURPHY, R.C. 1936. Oceanic birds of South America. [2 vols.] New York, NY: Macmillan Co. 1245 pp.

PIATT, J.F. 1990. The aggregative response of Common Murres and Atlantic Puffins to schools of Capelin. *Studies in Avian Biology* 14: 36–51.

ROSE, G.A. & LEGGETT, W.C. 1990. The importance of scale to predator-prey spatial correlations: an example of Atlantic fishes. *Ecology* 71: 33–43.

SCHNEIDER, D.C. & PIATT, J.F. 1986. Scale-dependent correlation of seabirds with schooling fish in a coastal ecosystem. *Marine Ecology Progress Series* 32: 237–246.

TASKER, M.L., JONES, P.H., DIXON, T. & BLAKE, B.F. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized methodology. *Auk* 101: 567–577.

VEIT, R.R., SILVERMAN, E.D. & EVERSON, I. 1993. Aggregation patterns of pelagic predators and their principal prey, Antarctic krill, near South Georgia. *Journal of Animal Ecology* 62: 551–564.

VEIT, R.R., SANTORA, J.A. & OWEN, H. 2008. Krill, Dec 15 [video file]. Available online at: www.ocean.washington.edu/people/faculty/grunbaum/Krill_Dec15.avi; cited 23 January 2009.

WARHAM, J. 1996. The behaviour, population biology and physiology of the petrels. London, UK: Academic Press. 613 pp.

WEBER, L.H., EL-SAYED, S.Z. & HAMPTON, I. 1986. The variance spectra of phytoplankton, krill and water temperature in the Antarctic Ocean south of Africa. *Deep-Sea Research* 33: 1327–1343.

WIEBE, P.H., GREENE, C.H., STANTON, T.K. & BURCZYNSKI, J. 1990. Sound scattering by live zooplankton and micronekton: empirical studies with a dual-beam acoustical system. *Journal of the Acoustical Society of America* 88: 2346–2360.