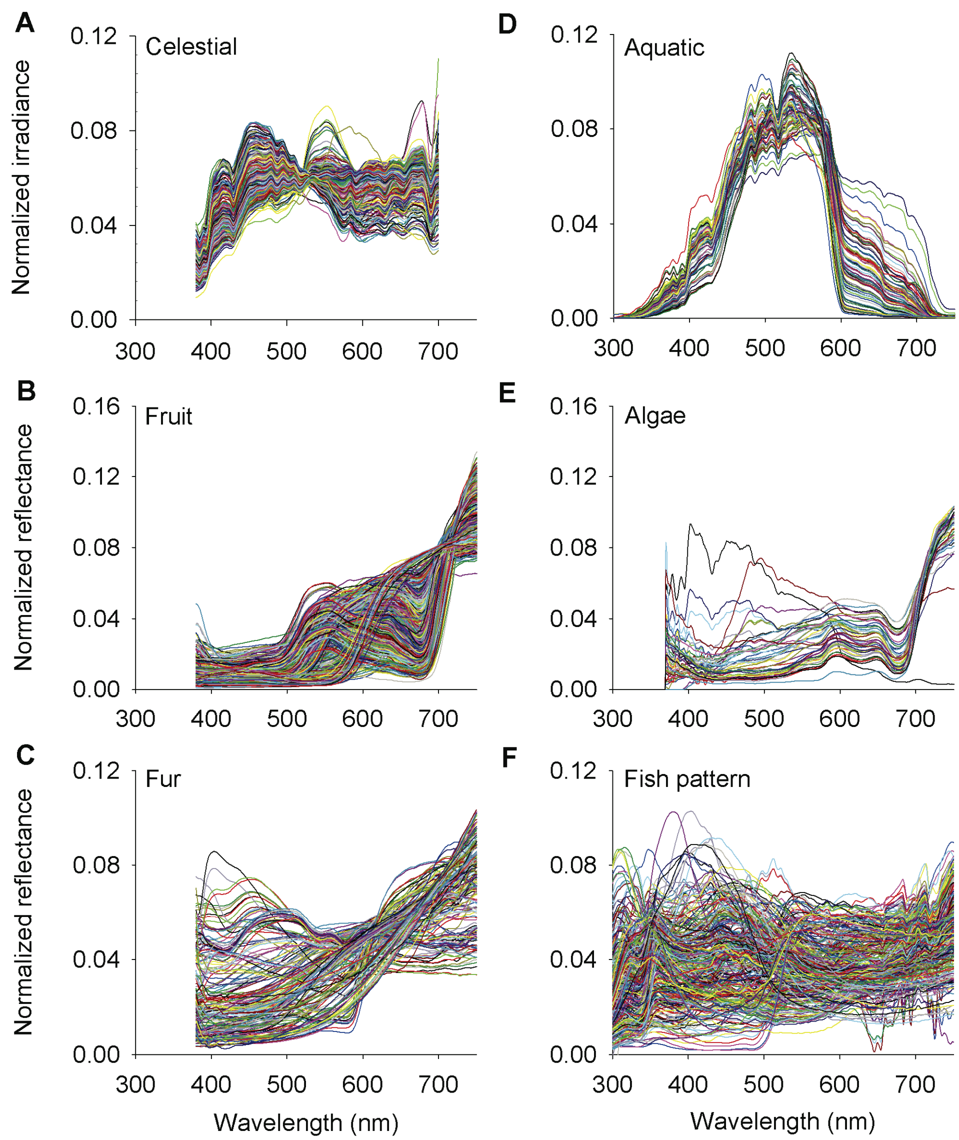

Fig. S1. Irradiance and surface reflectance spectra analysed.
(A) Celestial and (D) aquatic irradiance spectra as well as reflectance spectra of (B-C) terrestrial and (E-F) aquatic objects were analysed. Spectra were spline interpolated at a 1 nm interval and normalized to the length of one (by normalizing each spectrum by its norm). To test the effect of four algae reflectance outliers shown in (E), PCA and DFT were performed once for the original algae reflectance data set and again after omitting the outliers. For PCA, the variance accounted for by models of one through ten PCs did not differ between the original and reduced data sets. For DFT, the median band-limit was 9.77 and 9.87 for the original and reduced data set. Thus, the observed outliers had no practical effect on the estimated complexity of algae reflectance.

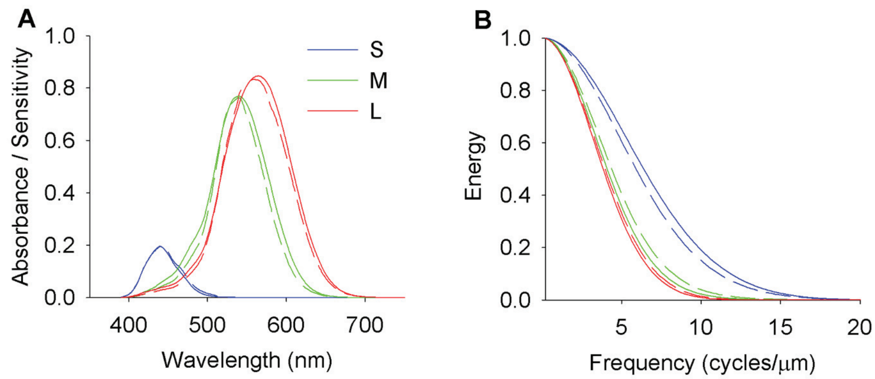

Fig. S2. Absorbance and sensitivity of cone photoreceptors in humans.
Absorbance spectra for the S-, M-, and L-cone photoreceptors in humans (blue, green, and red solid lines, respectively) were generated based on visual pigment absorbance templates and were corrected for lens and macula transmission. Corrected absorbance spectra were quantitatively similar to the commonly used sensitivity spectra (dashed lines) for humans in the (A) wavelength and (B) frequency domains. The band-limits of cone photoreceptors based on corrected absorbance spectra equaled 14.45, 9.57, and 8.39 cycles μm^{-1}, whereas, the band-limits of cone photoreceptors based on sensitivity spectra equaled 13.87, 10.55, and 8.79 cycles μm^{-1} for the S-, M-, and L-cone photoreceptors.

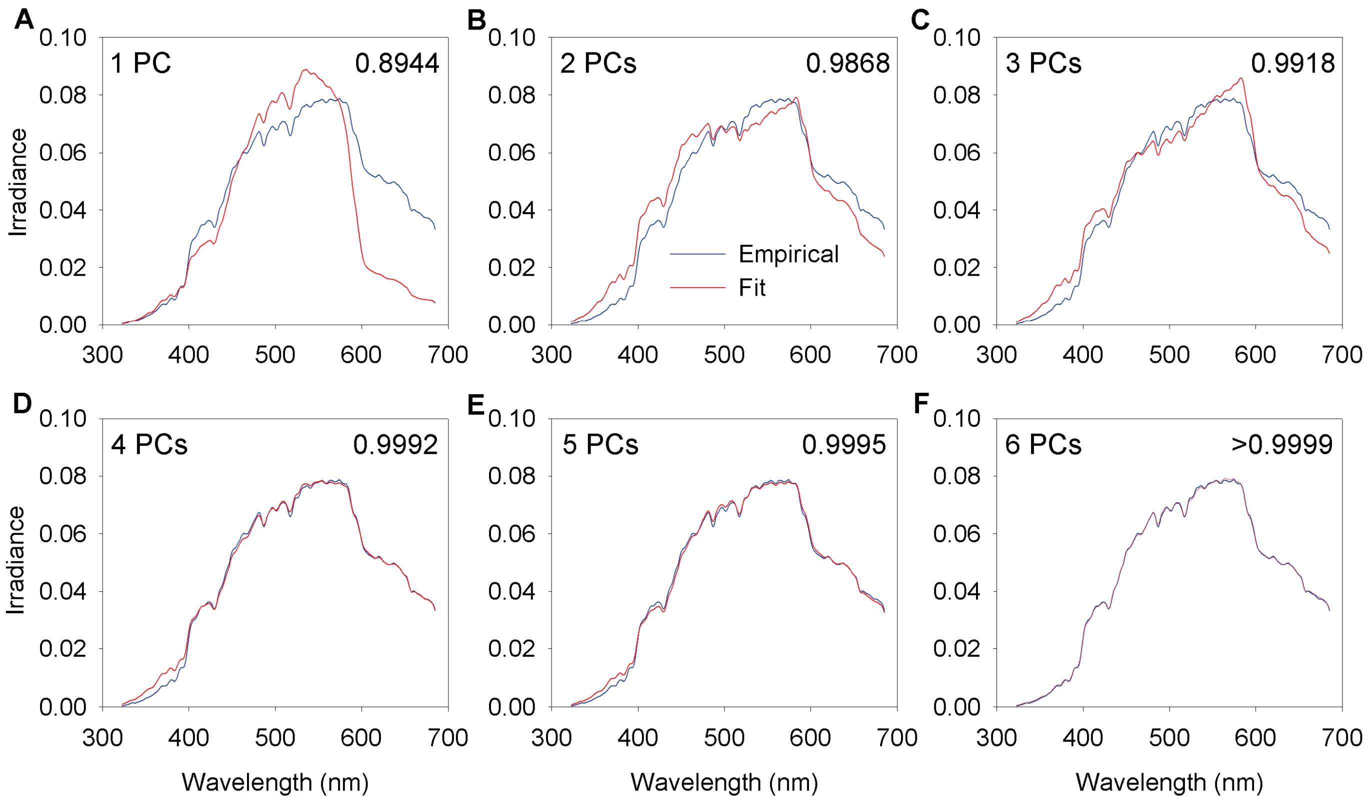

Fig. S3. Example procedure of fitting a spectrum to linear models.
An aquatic irradiance spectrum fitted to a linear model of one through six principal components (A-F). The goodness of fit, R^2 (top right corner of plots), increases with the number of principal components (PCs) included in the model. It is unknown how accurately animals reconstruct spectra. Thus, the number of PCs required for signal reconstruction was defined as the number of PCs required to exceed a variance criterion of R^2=0.99. Therefore, the given signal can be reconstructed with the first 3 PCs. This procedure was repeated for all spectra in a collection.

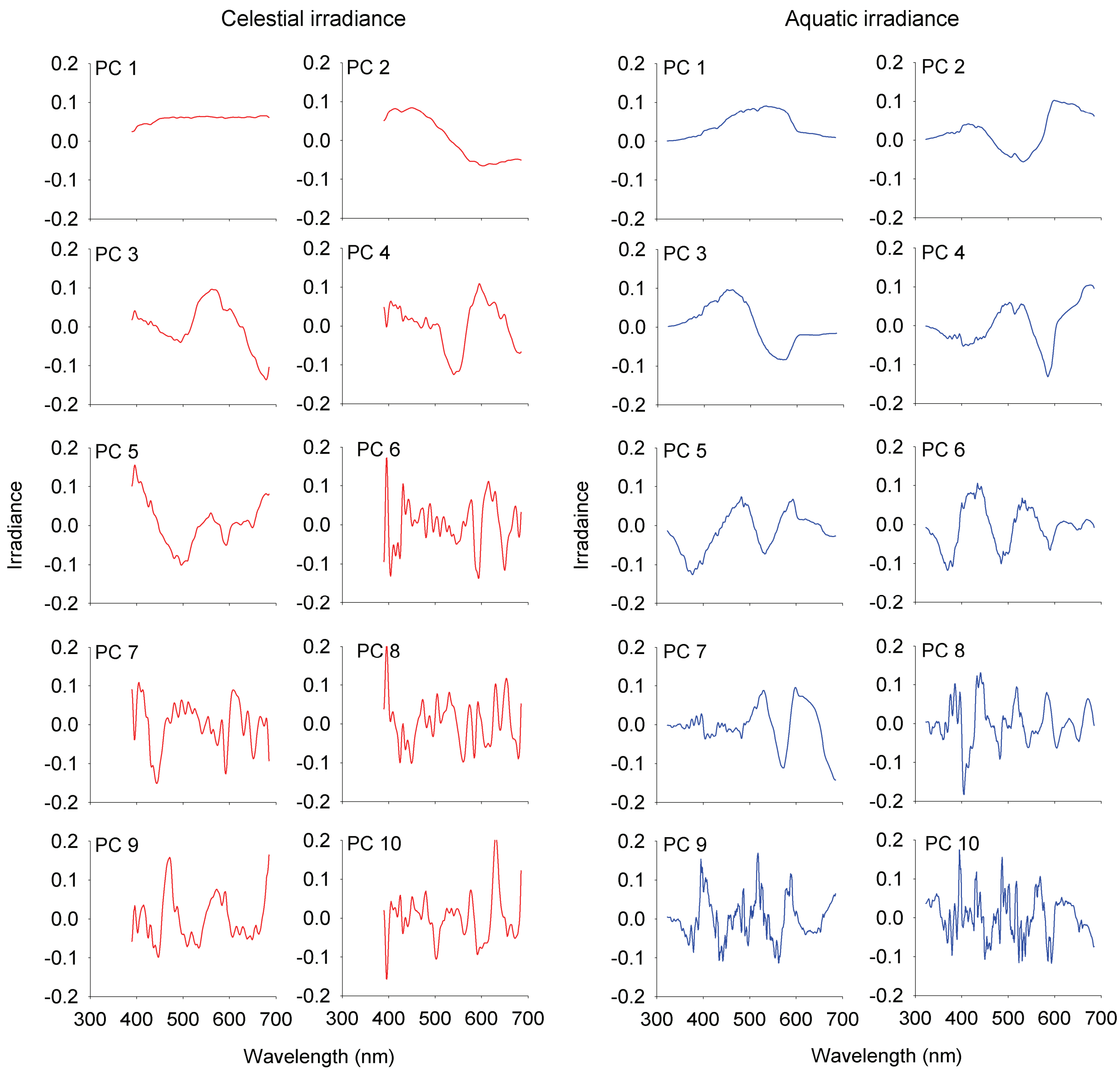

Fig. S4. The first 10 PCs (PC 1 – PC 10) for celestial and aquatic irradiance.
The spectrum of PC 1 of celestial and aquatic irradiance showed low comb frequencies across wavelengths, and resembled the general shape of celestial and aquatic irradiance spectra, respectively. However, when moving from PC 1 through PC 10, the high-frequency content in the spectrum of PCs increased gradually.

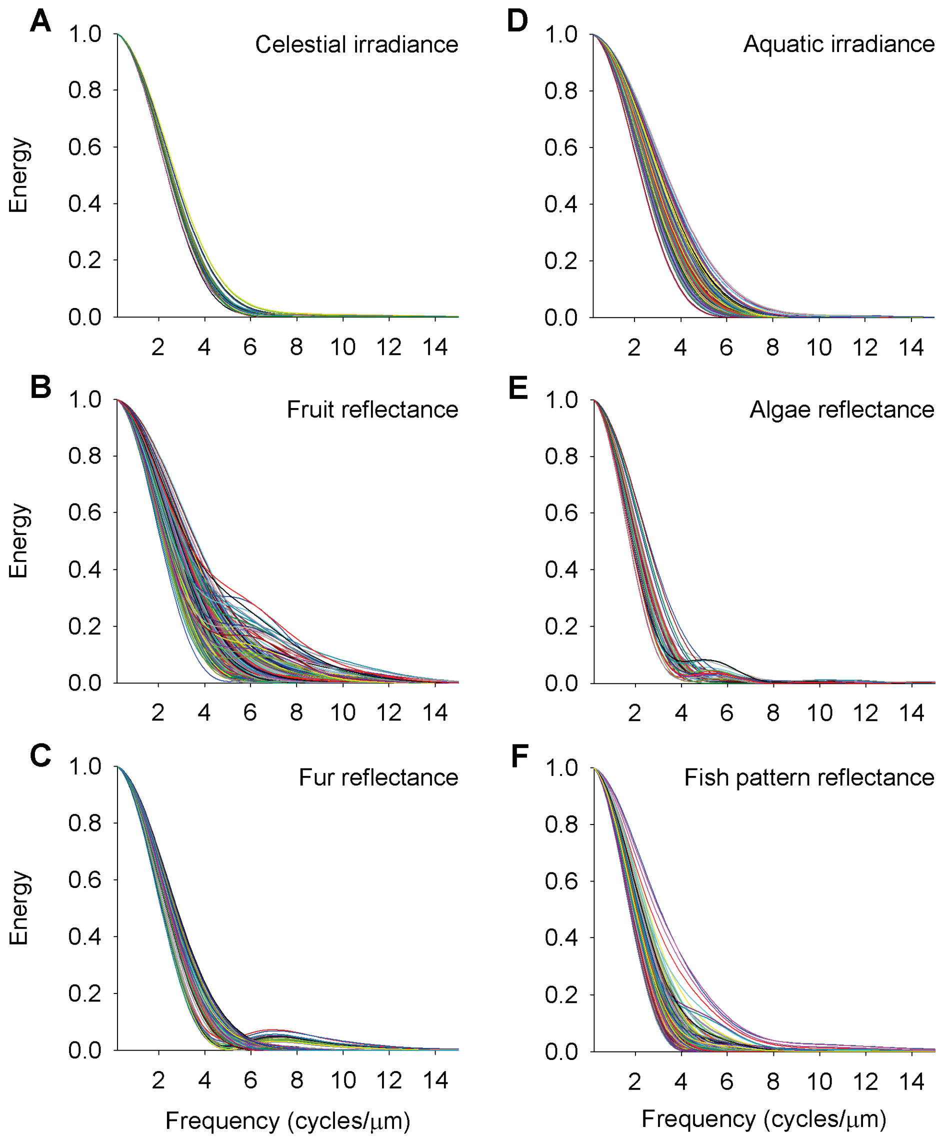

Fig. S5. Irradiance and object reflectance expressed as band-limited functions.
(A) Celestial and (D) aquatic irradiance as well as reflectance spectra of (B-C) terrestrial and (E-F) aquatic objects were expressed as band-limited functions.

Table S1. Band-limits of fish cone photoreceptors for different combinations of chromophore and lens transmission.

Chromophore	Lens T_{50} (nm)	SWS1	SWS2b	SWS2a	Rh2b	Rh2aα	Rh2aβ	LWS
A_1	350	16.02	10.35	8.98	8.20	7.62	7.42	7.23
	400	n.a.	11.72	9.38	8.59	7.81	7.62	7.42
A_2	350	10.55	8.40	7.62	7.03	6.25	6.05	5.66
	400	n.a.	9.38	8.01	7.23	6.45	6.25	5.86

The band-limits (cycles μm^{-1}) of cone photoreceptors in fish depended on chromophore content and lens transmission. The band-limits of cone photoreceptors in fish that exhibited A_1 retina were higher than in fish that exhibited A_2 retina. Additionally, the band-limits of cone photoreceptors in fish with a non-UV-transmissive lens (T_{50} = 400 nm) were slightly higher than in fish with a UV-transmissive lens (T_{50} = 350 nm). However, fish that exhibit non-UV-transmissive lenses typically do not possess the SWS1 (UV) cone photoreceptor, and thus, in these cases, the band-limits of the SWS1 photoreceptor are not shown. Consequently, fish with A_1 retina and a UV-transmissive lens would recover higher frequencies from the colour signal of objects viewed.