Supplementary Table S9. Benchmark results for the recall of CS prediction at four different tolerance windows. The bold value represents the highest recall among the predictors in a particular tolerance window. The SP type indicated with the symbol † represents SP types with limited training samples.

Method/backbone		Baseline	Fine-tuning			Prompt Tuning			Adapter Tuning			LoRA		
Organism	window	SignalP 6.0	ESM2-150M	ESM2-650M	ESM2-3B	ESM2-150M	ESM2-650M	ESM2-3B	ESM2-150M	ESM2-650M	ESM2-3B	ESM2-150M	ESM2-650M	ESM2-3B
Archaea Sec/SPI	±0	0.575	0.547	**0.640**	0.570	0.490	0.575	0.575	0.612	0.625	0.611	0.603	0.531	0.612
	±1	0.632	0.623	**0.697**	0.651	0.557	0.642	0.651	0.688	**0.697**	0.673	0.642	0.618	0.679
	±2	0.632	0.632	0.697	0.651	0.557	0.642	0.651	**0.706**	0.697	0.682	0.651	0.618	0.679
	±3	0.671	0.662	0.727	0.680	0.586	0.690	0.680	**0.736**	0.727	**0.736**	0.690	0.647	0.708
Archaea Sec/SPII	±0	0.806	0.806	0.861	0.861	0.706	0.875	0.667	0.875	0.778	0.806	**0.917**	0.875	0.764
	±1	0.806	0.806	0.861	0.861	0.706	0.875	0.667	0.875	0.778	0.806	**0.917**	0.875	0.764
	±2	0.806	0.806	0.861	0.861	0.706	0.875	0.667	0.875	0.778	0.806	**0.917**	0.875	0.764
	±3	0.806	0.806	0.861	0.861	0.706	0.875	0.708	0.875	0.778	0.806	**0.917**	0.875	0.764
Archaea Sec/SPIII	±0	0.500	0.417	0.389	**0.861**	0.278	0.528	0.500	0.556	0.750	0.500	0.389	0.389	0.417
	±1	0.500	0.417	0.389	**0.861**	0.278	0.528	0.500	0.667	0.750	0.500	0.444	0.417	0.472
	±2	0.500	0.417	0.389	**0.861**	0.278	0.528	0.500	0.750	0.750	0.500	0.444	0.417	0.611
	±3	0.500	0.417	0.389	**0.861**	0.278	0.528	0.500	0.750	0.750	0.500	0.444	0.417	0.611
Archaea Tat/SPI	±0	0.292	0.333	0.292	0.226	0.155	0.226	0.286	0.220	**0.351**	0.268	0.310	0.310	0.268
	±1	0.363	0.405	0.339	0.274	0.179	0.274	0.405	0.315	**0.446**	0.315	0.405	0.405	0.292
	±2	0.363	0.405	0.363	0.274	0.250	0.345	0.405	0.315	**0.446**	0.315	0.405	0.429	0.339
	±3	0.429	0.470	0.446	0.339	0.292	0.387	0.488	0.423	**0.571**	0.381	0.488	0.512	0.405
Archaea Tat/SPII	±0	0.688	0.812	**1.000**	0.875	0.312	0.438	0.250	0.625	**1.000**	0.812	0.750	0.812	**1.000**
	±1	0.812	0.812	**1.000**	0.875	0.312	0.438	0.250	0.625	**1.000**	0.812	0.750	0.812	**1.000**
	±2	0.812	0.812	**1.000**	0.875	0.312	0.438	0.250	0.625	**1.000**	0.812	0.750	0.812	**1.000**
	±3	0.812	0.812	**1.000**	0.875	0.312	0.438	0.250	0.625	**1.000**	0.812	0.750	0.875	**1.000**
Eukarya Sec/SPI	±0	0.817	0.825	0.839	0.835	0.825	0.828	0.835	0.826	0.827	**0.846**	0.821	0.776	0.827
	±1	0.858	0.860	0.877	0.873	0.861	0.861	0.867	0.866	0.864	**0.882**	0.858	0.830	0.866
	±2	0.900	0.887	0.910	0.904	0.891	0.888	0.894	0.897	0.894	**0.910**	0.889	0.881	0.901
	±3	0.920	0.904	0.925	0.920	0.907	0.902	0.908	0.917	0.909	**0.926**	0.905	0.904	0.920
Negative Sec/SPI	±0	0.855	0.789	0.847	0.873	0.790	0.774	0.819	0.862	0.889	**0.894**	0.839	0.850	0.858
	±1	0.886	0.830	0.875	0.906	0.819	0.793	0.840	0.904	0.912	**0.925**	0.872	0.889	0.895
	±2	0.892	0.841	0.887	0.921	0.826	0.798	0.847	0.911	0.915	**0.933**	0.885	0.904	0.900
	±3	0.898	0.849	0.895	0.928	0.828	0.802	0.850	0.921	0.920	**0.938**	0.892	0.909	0.908
Negative Sec/SPII	±0	0.935	0.947	0.948	0.947	0.885	0.945	0.925	0.938	0.949	0.947	**0.954**	0.944	0.951
	±1	0.936	0.947	0.948	0.947	0.885	0.945	0.927	0.938	0.949	0.947	**0.955**	0.944	0.951
	±2	0.936	0.947	0.948	0.947	0.885	0.945	0.927	0.938	0.949	0.947	**0.955**	0.945	0.951
	±3	0.937	0.947	0.949	0.948	0.885	0.946	0.929	0.939	0.950	0.948	**0.956**	0.945	0.952

Method/backbone Organism	window	Baseline SignalP 6.0	Fine-tuning			Prompt Tuning			Adapter Tuning			LoRA		
			ESM2-150M	ESM2-650M	ESM2-3B	ESM2-150M	ESM2-650M	ESM2-3B	ESM2-150M	ESM2-650M	ESM2-3B	ESM2-150M	ESM2-650M	ESM2-3B
Negative Sec/SPIII	±0	0.842	0.993	0.952	0.959	0.928	0.978	0.964	**1.000**	**1.000**	0.899	0.816	0.391	0.739
	±1	0.842	0.993	0.952	0.959	0.928	0.978	0.964	**1.000**	**1.000**	0.899	0.859	0.591	0.739
	±2	0.842	0.993	0.952	0.993	0.928	0.978	0.964	**1.000**	**1.000**	0.899	0.859	0.765	0.739
	±3	0.842	0.993	0.952	0.993	0.928	0.978	0.964	**1.000**	**1.000**	0.899	0.859	0.859	0.900
Negative Tat/SPI	±0	0.782	0.788	0.781	0.716	0.656	0.772	0.649	0.776	0.792	0.712	**0.805**	0.771	0.711
	±1	0.839	0.833	0.828	0.773	0.698	0.817	0.703	0.816	0.847	0.763	**0.852**	0.815	0.764
	±2	0.892	0.882	0.879	0.816	0.732	0.867	0.738	0.865	0.891	0.802	**0.904**	0.886	0.878
	±3	0.914	0.906	0.891	0.828	0.754	0.878	0.752	0.894	0.913	0.815	**0.916**	0.902	0.904
Negative Tat/SPII	±0	0.431	0.505	0.523	0.458	0.097	0.347	0.375	0.375	**0.542**	0.486	0.306	0.500	**0.542**
	±1	0.523	0.505	0.523	0.458	0.097	0.347	0.375	0.375	**0.542**	0.486	0.306	0.500	**0.542**
	±2	0.523	0.505	0.523	0.458	0.097	0.384	0.375	0.375	**0.542**	0.486	0.306	0.500	**0.542**
	±3	0.523	0.505	0.523	0.458	0.097	0.384	0.375	0.375	**0.542**	0.486	0.306	0.500	**0.542**
Positive Sec/SPI	±0	0.766	0.807	**0.820**	0.809	0.745	0.671	0.752	0.803	0.814	0.816	0.785	0.732	0.813
	±1	0.779	0.818	0.830	0.826	0.750	0.679	0.763	0.819	**0.838**	0.838	0.796	0.741	0.832
	±2	0.794	0.833	0.848	0.841	0.769	0.692	0.772	0.834	**0.855**	0.853	0.816	0.756	0.852
	±3	0.812	0.839	0.854	0.859	0.777	0.698	0.778	0.840	**0.861**	0.859	0.825	0.774	0.860
Positive Sec/SPII	±0	0.870	0.901	0.911	0.890	0.800	0.872	0.866	0.912	0.881	0.898	**0.929**	0.903	0.921
	±1	0.870	0.901	0.911	0.890	0.802	0.872	0.866	0.912	0.881	0.898	**0.929**	0.903	0.921
	±2	0.871	0.901	0.911	0.890	0.802	0.872	0.866	0.912	0.881	0.898	**0.929**	0.903	0.921
	±3	0.871	0.901	0.911	0.890	0.802	0.872	0.866	0.912	0.881	0.898	**0.929**	0.903	0.921
Positive Sec/SPIII	±0	**1.000**	**1.000**	0.917	**1.000**	0.833	**1.000**	0.750	**1.000**	**1.000**	**1.000**	0.750	0.500	0.833
	±1	**1.000**	**1.000**	0.917	**1.000**	0.833	**1.000**	0.750	**1.000**	**1.000**	**1.000**	0.917	0.667	0.833
	±2	**1.000**	**1.000**	0.917	**1.000**	0.833	**1.000**	0.750	**1.000**	**1.000**	**1.000**	0.917	0.833	0.833
	±3	**1.000**	**1.000**	0.917	**1.000**	0.833	**1.000**	0.750	**1.000**	**1.000**	**1.000**	0.917	0.833	**1.000**
Positive Tat/SPI	±0	0.396	0.526	0.485	0.411	0.406	0.430	0.265	0.389	0.494	0.387	0.444	0.511	**0.550**
	±1	0.457	0.526	0.507	0.411	0.406	0.450	0.285	0.400	0.494	0.415	0.465	0.533	**0.550**
	±2	0.669	0.741	0.672	0.576	0.506	0.633	0.431	0.633	0.641	0.611	0.691	0.733	**0.765**
	±3	0.669	0.741	0.700	0.604	0.543	0.633	0.431	0.633	0.641	0.611	0.691	0.733	**0.765**
Positive Tat/SPII	±0	**1.000**	0.861	0.972	0.972	0.361	0.194	0.194	0.722	0.694	**1.000**	0.611	0.667	0.972
	±1	**1.000**	0.889	0.972	0.972	0.361	0.194	0.194	0.722	0.694	**1.000**	0.611	0.667	0.972
	±2	**1.000**	0.889	0.972	0.972	0.361	0.194	0.194	0.722	0.694	**1.000**	0.611	0.667	0.972
	±3	**1.000**	0.889	0.972	0.972	0.361	0.194	0.194	0.722	0.694	**1.000**	0.611	0.667	0.972
mean		0.761	0.768	0.785	0.792	0.599	0.679	0.630	0.755	**0.799**	0.767	0.729	0.716	0.775